Comis, Sue

From: Awad, Isam
Sent: Monday, April 28, 2008 8:32 AM
To: Comis, Sue
Subject: FW: Emailing: P801_-_CDRL_11-6_Rev_0_-_Car_Body_Roll_Control_Method_04-07-05.pdf, P801_-_CDRL_11-6_Rev_0_-_ER2013_Carbody_Roll_Control_07-25-06.pdf

Follow Up Flag: Follow up
Flag Status: Red

fyi

-----Original Message-----
From: Garrod, Justin
Sent: Tuesday, April 22, 2008 4:48 PM
To: Awad, Isam
Subject: FW: Emailing: P801_-_CDRL_11-6_Rev_0_-_Car_Body_Roll_Control_Method_04-07-05.pdf, P801_-_CDRL_11-6_Rev_0_-_ER2013_Carbody_Roll_Control_07-25-06.pdf

I hope this helps.

Thanks,

Justin Garrod, PMP
Project Manager, Light Rail Vehicle
Link Light Rail
Phone: (206) 398-5384
Cell: (206) 396-4379
Fax: (206) 689-3351
justin.garrod@soundtransit.org

-----Original Message-----
From: Takeda, Sabro [mailto:STakeda@ltk.com]
Sent: Tuesday, April 22, 2008 4:46 PM
To: Garrod, Justin
Subject: RE: Emailing: P801_-_CDRL_11-6_Rev_0_-_Car_Body_Roll_Control_Method_04-07-05.pdf, P801_-_CDRL_11-6_Rev_0_-_ER2013_Carbody_Roll_Control_07-25-06.pdf

Justin:

Suspension data of the vehicle can be read from the document below:

Primary suspension stiffness:
Vertical - 2430 N/mm/axle
Lateral - 4400 N/mm/axle
Longitudinal - 32000 N/mm/axle

Secondary suspension stiffness:
Vertical - 393 N/mm/truck
Lateral - 267 N/mm/truck
Longitudinal - 267 N/mm/truck

Damping coefficient:
Axle spring (vertical) - 2500 N-s/m/truck Secondary suspension (vertical) - 104.6 N-s/mm/truck Lateral damper - 63.5 N-s/mm/truck

I listed the suspension figures at AW0 only since this is the most unstable condition in most cases. I did not include vehicle weight data (I thought you said you have them, correct?). Please let me know if you need more information about the vehicles. Thanks.

Sabro

-----Original Message-----

P801_-_CDRL_11-6_Rev_0_-_Car_Body_Roll_Control_Method_04-07-05.pdf
P801_-_CDRL_11-6_Rev_0_-_ER2013_Carbody_Roll_Control_07-25-06.pdf

Note: To protect against computer viruses, e-mail programs may prevent sending or receiving certain types of file attachments. Check your e-mail security settings to determine how attachments are handled.

Awad, Isam

From: Garrod, Justin
Sent: Wednesday, April 23, 2008 7:31 AM
To: Awad, Isam
Subject: FW: Spring constrants and other truck info for I-90
Importance: High

Isam,

Additional information from David Sanders, see below:

Thanks,

Justin Garrod, PMP
Project Manager, Light Rail Vehicle
Link Light Rail
Phone: (206) 398-5384
Cell: (206) 396-4379
Fax: (206) 689-3351
justin.garrod@soundtransit.org

From: Sanders, David [mailto:DSanders@ltk.com]
Sent: Wednesday, April 23, 2008 7:04 AM
To: Garrod, Justin
Subject: Spring constrants and other truck info for I-90
Importance: High

Justin,

The U-Link people also wanted truck info. It's hard to find in the design submittals so I asked Don, who got it from Komeda son.

Dave

-----Original Message-----
From: Don Boss [mailto:boss@killc.com]
Sent: Wednesday, April 09, 2008 7:17 AM
To: Sanders, David
Subject: Truck Weights

Thank you.

Donald Boss
Manager of Projects
Kinkisharyo International, LLC
2100 Garden Drive, Suite 201
Mars, PA 16046

Phone: 724-778-0100 (240)
Fax: 724-778-0101
Cell: 412-443-2808
Email: boss@killc.com
Web: www.kinkisharyo.com

From: Sanders, David [mailto:DSanders@ltk.com]
Sent: Wednesday, April 09, 2008 10:08 AM
To: Don Boss
Subject: RE: Truck Weights

Don,

Thank you. Dr. Nelson is the noise and vibration expert working on the University Link extension.

Dave

> -----Original Message-----
> **From:** Don Boss [mailto:boss@killc.com]
> **Sent:** Wednesday, April 09, 2008 4:20 AM
> **To:** Sanders, David
> **Cc:** 'Porter, Denny'; Fennig, Jeff
> **Subject:** Truck Weights
>
> Dave the following details were provided by Komeda san,
>
> 1. Drive axle set with brake disc, journal bearings and flex.coupling= 810kg/ axle set
> 2. Idler wheel with brake disc and bearings= 290kg/ wheel
> 3. Bochum tire and wheel center; sorry data isn't available.
> 4. drive axle weight= 180kg/ axle
> 5. brake disc for drive axle= 60kg/ disc
> 6. brake disc for idler axle weight= 35kg/ disc
> 7. traction motor= 450 kg/ motor
> 8. gearbox= 370kg/ gearbox
> 9. truck frame, motor=1000kg, trailer= 850kg
> 10. stiffness, primary suspension
>   motor truck: 1.24kN/mm/box- vertical
>   trailer truck: 1.35kN/mm/box- vertical
> 11. stiffness, secondary suspension
>   motor truck: 400N/mm/air spring- vertical
>   trailer truck: 425N/mm/air spring- vertical
> 12. Bochum 85 wheel spring; sorry data isn't available.
>
> Donald Boss
> Manager of Projects
> Kinkisharyo International, LLC
> 2100 Garden Drive, Suite 201
> Mars, PA 16046
>
> Phone: 724-778-0100 (240)
> Fax: 724-778-0101
> Cell: 412-443-2808
> Email: boss@killc.com
> Web: www.kinkisharyo.com
>
>

From: Sanders, David [mailto:DSanders@ltk.com]
Sent: Tuesday, April 08, 2008 4:21 PM
To: Don Boss
Cc: Porter, Denny; Jeff Fennig
Subject: FW: Truck Weights

Don,

Could one of you mechanical designers answer some of these component weight questions. Any help will be appreciated.

Regards,

Dave

-----Original Message-----
From: Porter, Denny [mailto:denny.porter@soundtransit.org]
Sent: Tuesday, April 08, 2008 12:21 PM
To: Sanders, David
Subject: FW: Truck Weights

Sr LRV expert and Sound Transit vehicle consultant---further help!

DLP

From: JamesTNelson [mailto:jnelson@wiai.com]
Sent: Tuesday, April 08, 2008 1:21 PM
To: Porter, Denny
Subject: Re: Truck Weights

Yes to all.
The unsprung Bochum tire, center, axle, brake disc, motor, gearbox, and frame components are needed. If you have the drawings, we can make some estimates from the drawings.

Do you have the stiffnesses for the primary and secondary suspension? Also, the Bochum 85 wheel springs?

Thanks.

Jim

> ----- Original Message -----
> **From:** Porter, Denny
> **To:** jnelson@wiai.com
> **Cc:** Sanders, David ; Guthrie, Mike
> **Sent:** Tuesday, April 08, 2008 11:47 AM
> **Subject:** Truck Weights
>
> Jim---I have two CDs of truck dwgs and reports which I can express mail to you but it isn't so straightforward to find actual truck component weights.
>
> The assembled motor truck weighs approx 13,077 lbs and the truck frame 2,279 lbs.
>
> The assembled trailer truck weighs approx 8,536 lbs and the truck frame 1,800 lbs.
>
> Would you be interested in the weight of the axle assembly, ie the rotating portion of the motor truck, and the weight of the wheel assembly (including the brake disc, bearings, etc), ie the rotating portion of

the trailer truck?

DLP

12.7.4 Noise

A. Interior noise shall not exceed the following:

Vehicle stationary:	72 dBA
Vehicle operating (not in tunnel):	75 dBA
Vehicle operating (in tunnel):	80 dBA

B. Exterior noise, measured 50 feet from the centerline of the track, 5 feet above the ground, shall not exceed the following:

Vehicle stationary:	68 dBA
Vehicle accelerating/decelerating on tangent track at 40 mph (64 km/h):	75 dBA

12.7.5 Shock and Vibration

A. Vibrations anywhere on the vehicle floor, walls, ceiling panels, and seat frames shall not exceed the following:

Below 1.4 Hz: Maximum deflection (peak to peak)	0.10 in. (2.54 mm)
1.4 Hz to 20 Hz: Peak acceleration:	0.01 g. (0.10 m/s^2)
Above 20 Hz: Peak velocity:	0.03 in/s. (0.76mm/s)

B. All vehicle equipment shall operate without damage or degradation of performance when subjected to vibration and impact encountered during normal service, and shall be compliant with and tested in accordance with IEC 61373 standard, including all functional and durability requirements.

12.7.6 Ride Quality

The rms acceleration values shall not exceed the 4-hour, reduced comfort level (vertical)" and "2.5 hr, reduced comfort level (horizontal) boundaries derived from Figure 2a (vertical) and Figure 3a (horizontal) of ISO 2631 over the range of 1 Hz to 80 Hz, for all load conditions AW0 to AW3.

12.7.7 Flammability and Smoke Emission

A. All materials used in the construction of the car shall meet as a minimum the requirements of the U.S. Department of Transportation's Recommended Fire Safety Practices for Rail Passenger Car Materials Selection - January 1989 and NFPA 130.

16.4.9.7 Auxiliary Ac Power Supply

The Contractor shall operate the auxiliary ac power supply test instrumentation throughout all car performance testing to verify that the requirements of Sections 2 and 9 are met. The data recordings so taken shall be available for inspection by Sound Transit and shall be furnished to Sound Transit by the Contractor upon delivery of cars for acceptance. Data recordings which contain representative samples of the power supply operating characteristics, taken during the auxiliary ac power supply conformance tests and these car performance tests, shall be copied and included in an auxiliary ac power supply test report.

16.4.10 Operational

The first car shall be given an operational test of 4000 mi (6400 km) before conditional acceptance by Sound Transit. The operational tests shall be performed in Seattle after arrival of the car but prior to formal delivery of the car to Sound Transit for conditional acceptance. The car shall be instrumented during these tests to determine that all systems are functioning properly and to confirm the capability and accuracy of the MDS. The instrumentation shall be as specified in Section 16.4.9.2. The test shall be conducted in simulated revenue service, with an AW3 passenger load, stopping at every station and cycling the doors. The data recordings shall become part of the permanent record for the cars and shall be turned over to Sound Transit with the test report. With Sound Transit approval, the car diagnostic system may be used instead of instrumentation, if it can provide sufficient information to evaluate and document test results. (Procedure: CDRL 16-82) (Report: CDRL 16-83)

During the last 1000 mi (1600 km) of the test, there shall be no failures of equipment. If a failure occurs, the 1000 mi (1600 km) portion of the test for the car on which the failure occurred shall be repeated following correction and documentation of the failure.

16.4.11 Ride Quality

Ride quality tests shall be performed on one car and two car trains. The tests shall prove compliance with the ride quality specifications of Section 2.8.9. (Procedure: CDRL 16-84) (Report: CDRL 16-85)

As a minimum, ride quality tests shall consist of operating the trains at speeds of 25, 40, and 55 mph (40, 64, and 89 km/h) over track selected by Sound Transit, under two load conditions: AW0 and AW3. Instrumentation capable of measuring the magnitude of the vertical, longitudinal, and lateral shocks and vibrations experienced, shall be provided and monitored by the Contractor on at least one car of the test trains. Sensing units shall be located on the car floor above the intersection of the car longitudinal center line and a power truck transverse center line, on the articulation truck transverse centerline, at the center of the car between trucks, and at three seat locations to be determined by Sound Transit. Provision shall be made for recording vertical, lateral, and longitudinal shocks and vibrations concurrently.

Weights used in simulating passenger load shall be provided by the Contractor.

Acceptability of the ride quality will be determined by an analysis of the recorded root-mean-square accelerations.

In the event that the dynamic behavior of the trains do not meet the Specification requirements, the Contractor shall submit for Sound Transit review, within 60 calendar days, a program containing a mathematical analysis of the problem and a course of action for its correction. If authorized by Sound

Transit, the corrective measures shall be installed on the test train within 90 days at the expense of the Contractor, the train shall be retested, and, if the measures are successful, they shall be applied to all cars. If not successful, the analysis and corrective action steps shall be repeated, and the train retested until Specification compliance is attained.

16.4.12 Noise and Vibration

After equipment installation, noise and vibration tests shall be performed on one of the first three cars to confirm compliance with the requirements of Section 2.8. (Procedure: CDRL 16-86) (Report: CDRL 16-87)

Compliance with the Specification is to be based on measurements taken in essentially a free-field environment such as outdoors, away from any reflecting surfaces other than the ground, ties, and ballast, on track with newly ground, welded rail. Reflected sound shall be such as to not influence the directly radiated sound from the equipment measured by more than 2 dB. All measurements shall be made with an ambient sound level in the vicinity of the test measurement locations of not less than 10 dB below the noise produced by the equipment being measured, when evaluated using the same scale or octave band.

The tunnel noise requirements of Section 2.8.3 should be tested in both the existing and new Central Link tunnels.

For these tests, the following shall be recorded:

- Description of noise or vibration source being measured, including pertinent statistical information;
- Description of the environment where the noise or vibration source is measured, including a sketch showing source position;
- Operating conditions of noise or vibration source during measurements;
- Pertinent meteorological data;
- Locations and orientations of microphones with respect to noise source;
- Equipment used for making measurements;
- Description and measurements of ambient noises;
- Data obtained, including range of variation; and
- Instrument settings, corrections, and calibration records.

The results shall be evaluated and any corrective action required shall be approved by Sound Transit. After corrective action is taken, the applicable tests shall be rerun. If the corrective action is successful, it shall be applied to all cars. If not successful, these steps shall be repeated until Specification compliance is attained.

16.4.13 Horn and Bell

The horn and bell, as mounted on a completed car, shall be tested for compliance to the requirements of Section 5.1.3.2. This requires testing of both ends of a car. (Procedure: CDRL 16-88) (Report: CDRL 16-89)

16.4.14 Electromagnetic Compatibility

An electromagnetic compatibility test shall be performed on one car by methods referenced in Section 2.9 for compliance with those requirements and for the compatibility with Sound Transit's traction power

KINKISHARYO International, L.L.C.
Mitsui & Co. (U.S.A.), Inc.
Mitsui USA
2100 Garden Drive, Suite 201
Mars, Pennsylvania 16046
TELEPHONE: (724) 778-0100 FACSIMILE: (724) 778-0101
Sound Transit LRV Project – RTA/LR 101-02

(Copy e-mail)

RJC July 25, 2006
P801-KIST-01096

Justin Garrod
Vehicle Program Manager
Sound Transit
Union Station
401 South Jackson Street
Seattle, WA 98104-2826

RECEIVED AUG 0 2 2006

Subject: CDRL 11-6 Rev 0 (ER2013) Carbody Roll Control

Reference: STKI-00403
TS 11.3.8

Contract Ref: RTA/LR101-02

Dear Mr. Garrod:

In response to the comments contained in ST letter STKI-00403 KI provides the following.

<u>ST Comment 1</u>
The submitted analysis is acceptable for a normal run. In order to assure that the vehicle will never violate the dynamic clearance, please provide the absolute maximum roll angle of the carbody with one side of the air spring deflated, and one side of the primary suspensions contacting the vertical stop.

<u>KI Response 1</u>
The maximum roll angle of the carbody due to a deflated air spring on one side, Ts is calculated as follows;

$Ts = \tan^{-1}(30\text{ mm} / 1840\text{ mm}) = 0.93°$
Where: 30 mm = Inside gap of air spring, 22mm + deflection of emergency stop, 8mm
1840 mm = Distance across air springs

The maximum roll angle of the carbody due to one side of the primary suspension contacting the vertical stop, Tp is calculated as follows;

$Tp = \tan^{-1}(25\text{ mm} / 1150\text{ mm}) = 1.25°$
Where: 25 mm = Mechanical stop of primary suspension
1150 mm = Distance across primary suspensions

If you have any questions or require additional information please don't hesitate to contact me.

Sincerely,

Donald S. Boss
Program Manager
KINKISHARYO International L.L.C.

Enclosures: None

Cc: LTK – Mr. David Sanders

KINKISHARYO International L.L.C.

2100 Garden Drive
Suite 201
Mars, PA 16046

Phone: 724-778-0100
Fax: 724-778-0101

TRANSMITTAL
No. 00378

PROJECT: RTA/LR 101-02

RECEIVED APR 1 2 2005

DATE: 4/7/2005

TO: Sound Transit
Union Station
401 South Jackson Street
Seattle, WA 98104-2826

REF: P801-KIST-00378 TS-11.3.8
Ref: None
CDRL 11-6 ER2013Rev00

ATTN: Justin Garrod

WE ARE SENDING:	SUBMITTED FOR:	ACTION TAKEN:
☐ Shop Drawings	☑ Approval	☐ Approved as Submitted
☐ Letter	☐ Your Use	☐ Approved as Noted
☐ Prints	☑ As Requested	☐ Returned After Loan
☐ Change Order	☐ Review and Comment	☐ Resubmit
☐ Plans		☐ Submit
☐ Samples	**SENT VIA:**	☐ Returned
☐ Specifications	☑ Attached	☐ Returned for Corrections
☑ Other: CDRL Submittal	☐ Separate Cover Via: Mail	☐ Due Date:

ITEM	PACKAGE	SUBMITTAL	DRAWING	REV.	ITEM NO.	COPIES	DATE	DESCRIPTION	STATUS
	CRL11-006	ER2013		001	01	5	4/7/2005	Car Body Roll Control Method Rev00	PEND

CC: David Sanders

Signed: [signature]
Donald S. Boss

Expedition®

KINKISHARYO International, L.L.C.

SOUND TRANSIT

CENTRAL PUGET SOUND REGIONAL TRANSIT AUTHORITY

Car Body Roll Control Method
ER2013

CDRL 11-6

DATE: March 31, 2005 REVISION: 0

Prepared by: T. Yamanaka

Reviewed by: G. Komeda

Approved by: D. Boss

REVISIONS

Revision	Description	Issue Date
0	Initial issue	03/31/05

Contents

1. General

This report describes the car body roll control method.

2. References to specification

Following requirements is applicable for CDRL 11-6.

11.3.8 car body roll stabilization

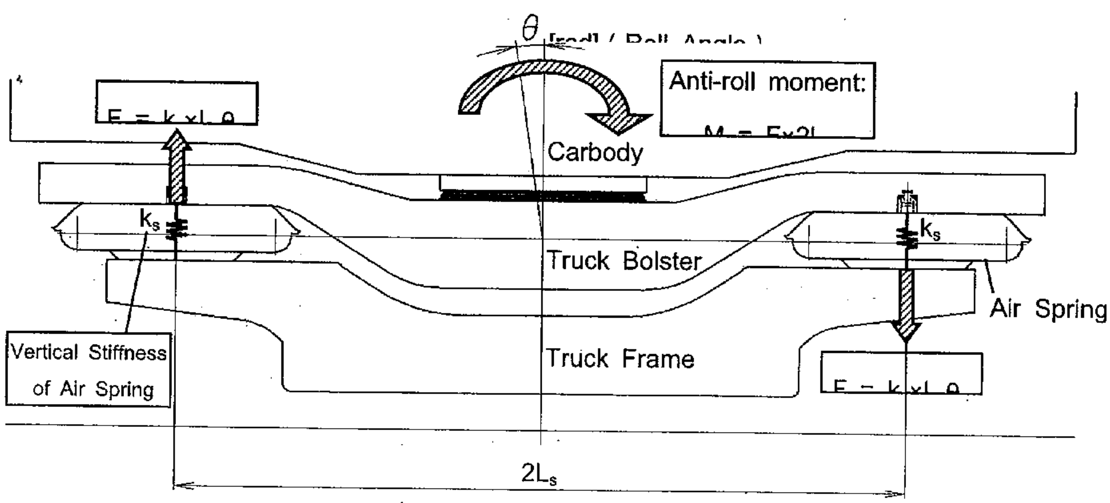
The suspension of each truck shall be designed to minimize car body roll. The exact value is to be defined by the contractor and approved by Sound Transit, but is not to exceed 3%. The method of controlling roll to keep the car body within the dynamic clearance outline of the vehicle shall be by torsion bars or other service proven method, subject to Sound Transit review and approval.

3. Proposed roll control design

The air springs will be mounted between the lateral end of the truck frame and the bolster. The car body roll will be controlled by an anti-roll moment presented by an air spring rate which is based on the equations indicated on the drawing below. The secondary suspension proposed for the ST LRV has been successfully used on the New Jersey Transit Hudson Bergen and Santa Clara Valley Transportation Authority LRVs.

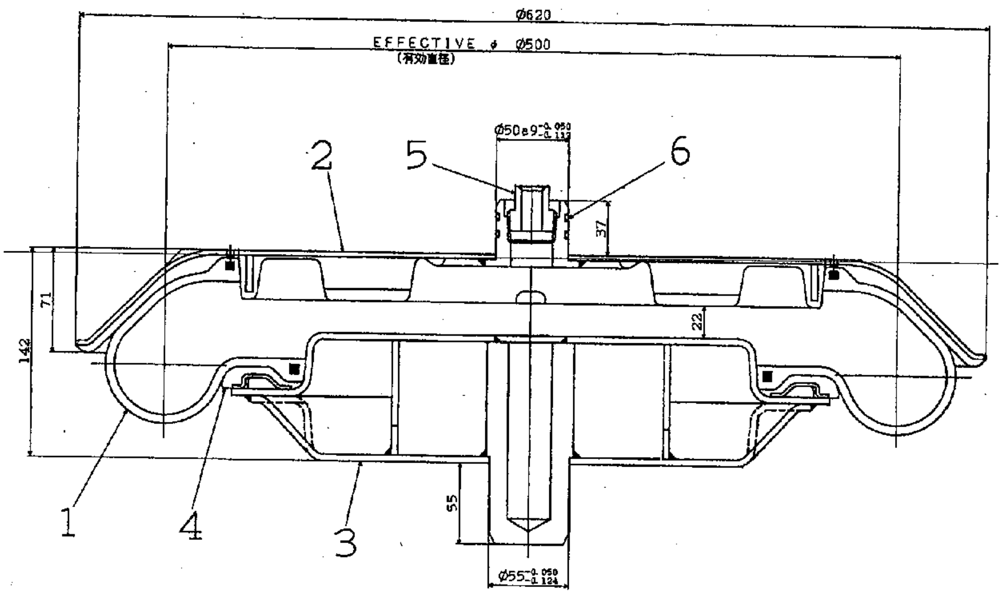
The calculated car body roll angle is detailed in Section 5 of this document.

Anti-roll moment;



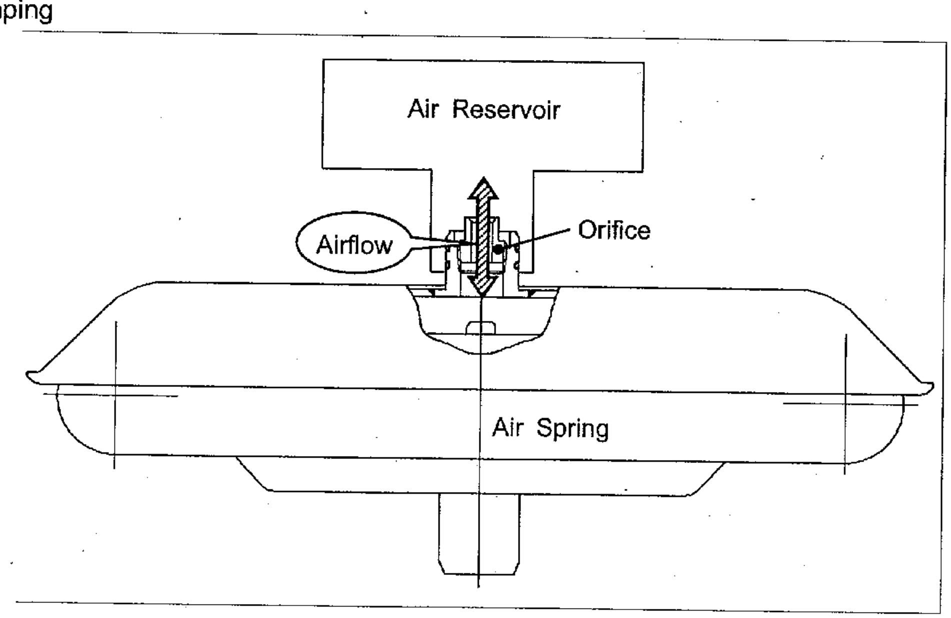
4. Air spring characteristics

4.1 Section of air spring



1. Diaphragm 2.Upper plate 3. Lower plate
4. Rubber seat 5. Orifice 6. O-ring

4.2 Damping



The orifice located between the air spring and the air reservoir creates a damping effect to reduce the vibration resonance.

4.3 Type test data

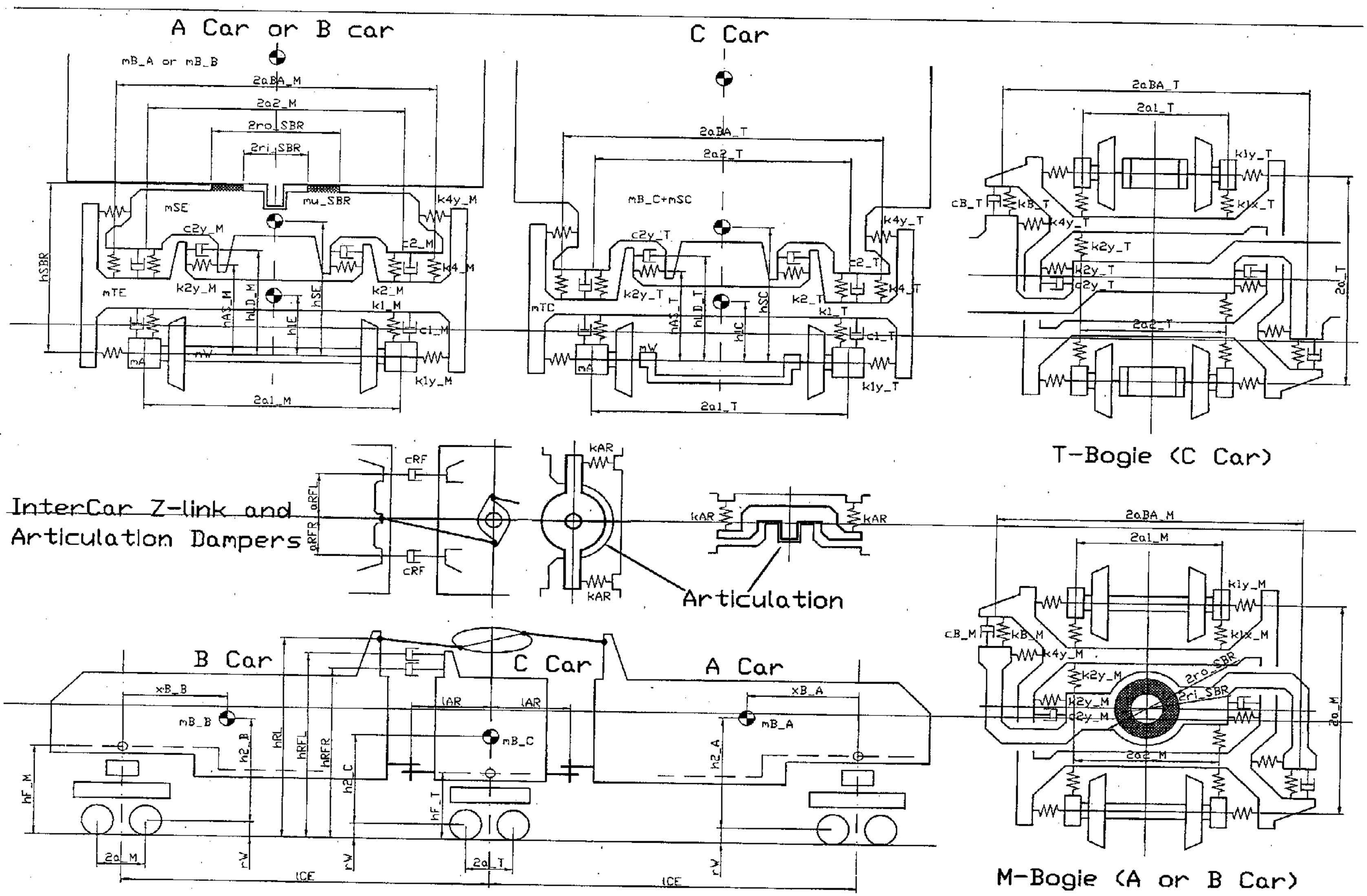
The technical data and characteristics for the 500mm air spring are shown in Appendix.1.

5. Carbody roll analysis

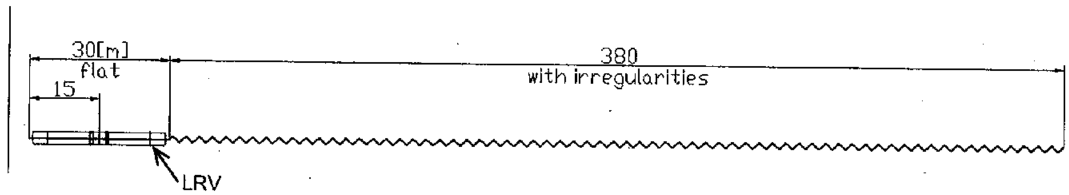
Carbody roll angle is analyzed by multi-body dynamics program, ADAMS/Rail as specified.

Table. Input Data for Dynamic analyses

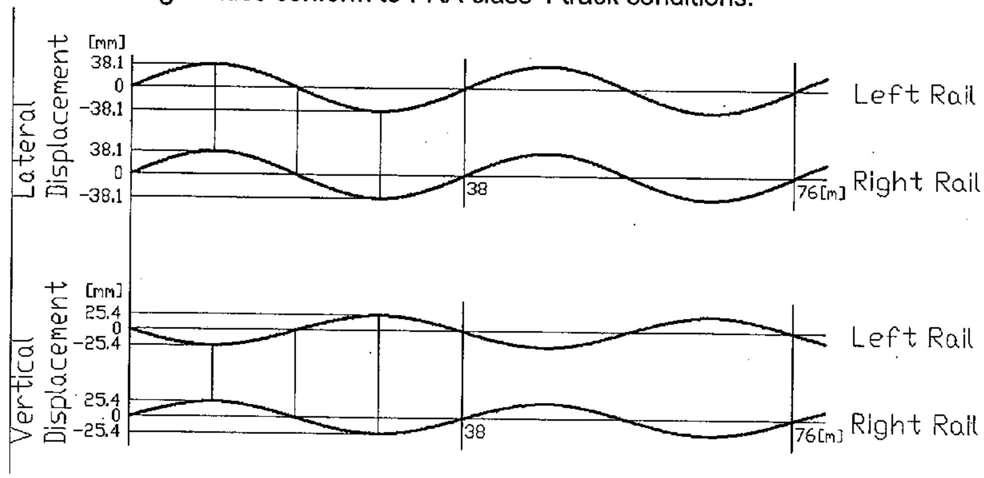
Category	Part		unit	VariableName A	VariableName B	VariableName C	AW0 A	AW0 B	AW0 C	AW1 A	AW1 B	AW1 C	AW2 A	AW2 B	AW2 C	AW3 A	AW3 B	AW3 C
Mass	**CarBody Mass**		kg/body	mB_A	mB_B	mB_C	13499	14374	3777	15739	16684	4477	19659	20604	5037	21689	22634	5177
	Bolster Mass		kg/bogie	mSE		mSC	570		300	570		300	570		300	570		300
	Bogie Sprung Mass		kg/bogie	mTE		mTC	4095		1215	4095		1215	4095		1215	4095		1215
	Bogie Unsprung Mass		kg/axle	mWE		mWC	1955		2635	1955		2635	1955		2635	1955		2635
	AxleBox Mass		kg/box	mA			50		115	50		115	50		115	50		115
	BolsterAnchor Mass		kg/rod	mBAM		mBAT	12		9.5	12		9.5	12		9.5	12		9.5
	ArticulationArm Mass		kg/body	mAP		-	50		-	50		-	50		-	50		-
	Articulation Bearing Mass		kg/body	mAR		-	30		-	30		-	30		-	30		-
	InterCarZ-link Mass		kg/rod	mRL		mRB	30		50	30		50	30		50	30		50
Inertia	Moment of Inertia, **CarBody**	Roll	kg-m²	IxBA	IxBB	IxBC	31600	33648	10787	36843	39056	12787	46020	48232	14386	50772	52984	14786
		Pitch	kg-m²	IyBA	IyBB	IyBC	173976	185253	6884	202846	215025	8159	253367	265546	9180	279530	291709	9435
		Yaw	kg-m²	IzBA	IzBB	IzBC	173976	185253	6884	202846	215025	8159	253367	265546	9180	279530	291709	9435
	Moment of Inertia, **Bogie SprungMass**	Roll	kg-m²	IxTE		IxTC	1481		1199	1481		1199	1481		1199	1481		1199
		Pitch	kg-m²	IyTE		IyTC	2184		1767	2184		1767	2184		1767	2184		1767
		Yaw	kg-m²	IzTE		IzTC	3023		2446	3023		2446	3023		2446	3023		2446
Stiffness	Stiffness, **AxleBox Guide**	Vertical	N/mm/axle	k1_M		k1_T	2430		2650	2430		2650	2430		2650	2610		2710
		Longitudinal	N/mm/axle	k1x_M		k1x_T	32000		32000	34320		36280	37270		41190	38250		44130
		Lateral	N/mm/axle	k1y_M		k1y_T	4400		4200	4610		4510	4710		4610	4810		4710
	Stiffness, **Bolster Spring**	Vertical	N/mm/htbogie	k2_A	k2_B	k2_C	393	406	425	452	467	486	527	544	620	570	583	682
		Longitudinal Lateral	N/mm/htbogie	k2y_A	k2y_B	k2y_C	267	271	279	291	297	305	323	329	357	339	344	377
	Stiffness, **BolsterAnchor**	Vertical	N/mm/htbogie	k4_M		k4_T	1.37e4		1.7e4	1.37e4		1.7e4	1.37e4		1.7e4	1.37e4		1.7e4
		Lateral	N/mm/htbogie	k4y_M		k4y_T	1.61e3		1.65e3	1.61e3		1.65e3	1.61e3		1.65e3	1.61e3		1.65e3
		Longitudinal	N/mm/htbogie	kB_M		kB_T	1.37e4		1.7e4	1.37e4		1.7e4	1.37e4		1.7e4	1.37e4		1.7e4
	Stiffness, **Articulation RubberBush**		N/m	kAR			115718470			115718470			115718470			115718470		
Damping	Coefficient of Damping, **Axle Spring**		N-s/mm/bogie	c1_M		c1_T	2.5		2.6	2.5		2.6	2.5		2.6	2.5		2.6
	Coefficient of Damping, **Bolster Spring**		N-s/mm/bogie	c2_A	c2_B	c2_C	104.6	108.2	113.4	121.4	125.4	133.1	143.1	147.9	169.1	155.1	158.7	187.2
	Coefficient of Damping, **Lateral Damper**		N-s/mm/bogie	c2y_M		c2y_T	63.5			63.5			63.5			63.5		
	Coefficient of Damping, **Articulation Damper**		N-s/m	-	cRF		-	5.88e5		-	5.88e5		-	5.88e5		-	5.88e5	
Vertical dimension	Radius of **Wheel**		m	hW			0.33			0.33			0.33			0.33		
	Height of Center of Gravity of **CarBody** from Axle		m	h2_A	h2_B	h2_C	1.51	1.51	1.275	1.432	1.435	1.183	1.369	1.374	1.167	1.347	1.353	1.164
	Height of **Floor** of CarBody from Rail		m	hF_M		hF_T	0.89		0.35	0.89		0.35	0.89		0.35	0.89		0.35
	Height of Center of Gravity of **Bolster** from Axle		m	hBE		hBC	0.23		0.247	0.23		0.247	0.23		0.247	0.23		0.247
	Height of **Side Bearing** of Bogie from Axle		m	hSBR		-	0.37		-	0.37		-	0.37		-	0.37		-
	Height of **InterCarZ-link** from Rail		m	hRL			3.2505			3.2505			3.2505			3.2505		
	Height of **Articulation Damper** from Rail	Right	m	-	hRFR		-	3.252		-	3.252		-	3.252		-	3.252	
		Left	m	-	hRFL		-	3.241		-	3.241		-	3.241		-	3.241	
	Height of Center of Gravity of **Bogie SprungMass** from Axle		m	h1E		h1C	0.05		0.05	0.05		0.05	0.05		0.05	0.05		0.05
	Height of **Bolster Spring** from Axle		m	hAS_M		hAS_T	0.23		0.247	0.23		0.247	0.23		0.247	0.23		0.247
	Height of **Lateral Damper** from Axle		m	hLD_M		hLD_T	0.29		0.11	0.29		0.11	0.29		0.11	0.29		0.11
Longitudinal dimension	Initial position of Center Bogie		m	-		xC	-		15	-		15	-		15	-		15
	Distance between **Bogie Centers**		m	lCE			10.922			10.922			10.922			10.922		
	Distance between **Articulation** from Center of Center Bogie		m	lAR			1.7			1.7			1.7			1.7		
	Harf of **Wheelbase**		m	a_M		a_T	0.95		0.9	0.95		0.9	0.95		0.9	0.95		0.9
	Longitudinal offset to Center of Gravity of Carbody from Bogie Center		m	xB_A	xB_B	-	2.45	2.45	-	2.45	2.45	-	2.45	2.45	-	2.45	2.45	-
	Length of Bolster Anchor		m	l4_M		l4_T	(0.65)		(0.45)	(0.65)		(0.45)	(0.65)		(0.45)	(0.65)		(0.45)
Lateral dimension	Half of Lateral Distance across **Axle Springs**		m	a1_M		a1_T	0.575		0.5985	0.575		0.5985	0.575		0.5985	0.575		0.5985
	Harf of Lateral Distance across **Bolster Springs**		m	a2_M		a2_T	0.92		0.9	0.92		0.9	0.92		0.9	0.92		0.9
	Harf of Lateral Distance across **Bolster Anchors**		m	aBA_M		aBA_T	1.16		1.05	1.16		1.05	1.16		1.05	1.16		1.05
	Lateral offset of **Lateral Damper**	on Bolster	m	aLDB_M		aLDB_T	1.12		0.9457	1.12		0.9457	1.12		0.9457	1.12		0.9457
		on Frame	m	aLDT_M		aLDT_T	0.777		0.7355	0.777		0.7355	0.777		0.7355	0.777		0.7355
	Lateral offset of **Articulation Damper**	Right	m	-		aRFR	-		0.45	-		0.45	-		0.45	-		0.45
		Left	m	-		aRFL	-		0.615	-		0.615	-		0.615	-		0.615
Others	Coefficient of Friction, **Side Bearing**		-	mu_SBR		-	0.45		-	0.45		-	0.45		-	0.45		-
	Outside Radius, **Side Bearing**		m	ro_SBR		-	0.25		-	0.25		-	0.25		-	0.25		-
	Inside Radius, **Side Bearing**		m	ri_SBR		-	0		-	0		-	0		-	0		-
	Clearance of **Lateral Bumpstop**		m	eLS_M		eLS_T	0.01		0.026	0.01		0.026	0.01		0.026	0.01		0.026


A Car or B car
C Car
T-Bogie (C Car)
InterCar Z-link and Articulation Dampers
Articulation
B Car
C Car
A Car
M-Bogie (A or B Car)

Dynamic (time domain) simulation is performed based on vehicle operation from 15[mph] to 65[mph] at 10[mph] increments on level tangent track with vertical and lateral irregularities as shown below.



Characteristic of irregularities conform to FRA class 4 track conditions.



(1) Calculation cases

Load state	AW0	AW1	AW2	AW3
Name of Case	C4-1	C4-2	C4-3	C4-4

(2) Criteria

The car body rolling angle does not exceed 1.7 degree ($\tan^{-1}(3/100)$) as per T.S.11.3.8.

(3) Results

The charts for the calculated car body roll angle analysis are shown below in Fig.1~4.
The table below contains a summary of the roll angle at the specified running speed of the vehicle;

(Unit: [deg])

Load state	AW0	AW1	AW2	AW3
Name of Case	C4-1	C4-2	C4-3	C4-4
15 mph	1.12	1.14	1.16	1.17
25 mph	1.37	1.39	1.45	1.46
35 mph	1.40	1.41	1.61	1.63
45 mph	1.30	1.31	1.35	1.35
55 mph	1.17	1.17	1.19	1.20
65 mph	1.04	1.04	1.06	1.07

(4) Conclusion

The design meets the specification requirements.

Fig.1 Carbody Roll Analysis (Case : C4-1)

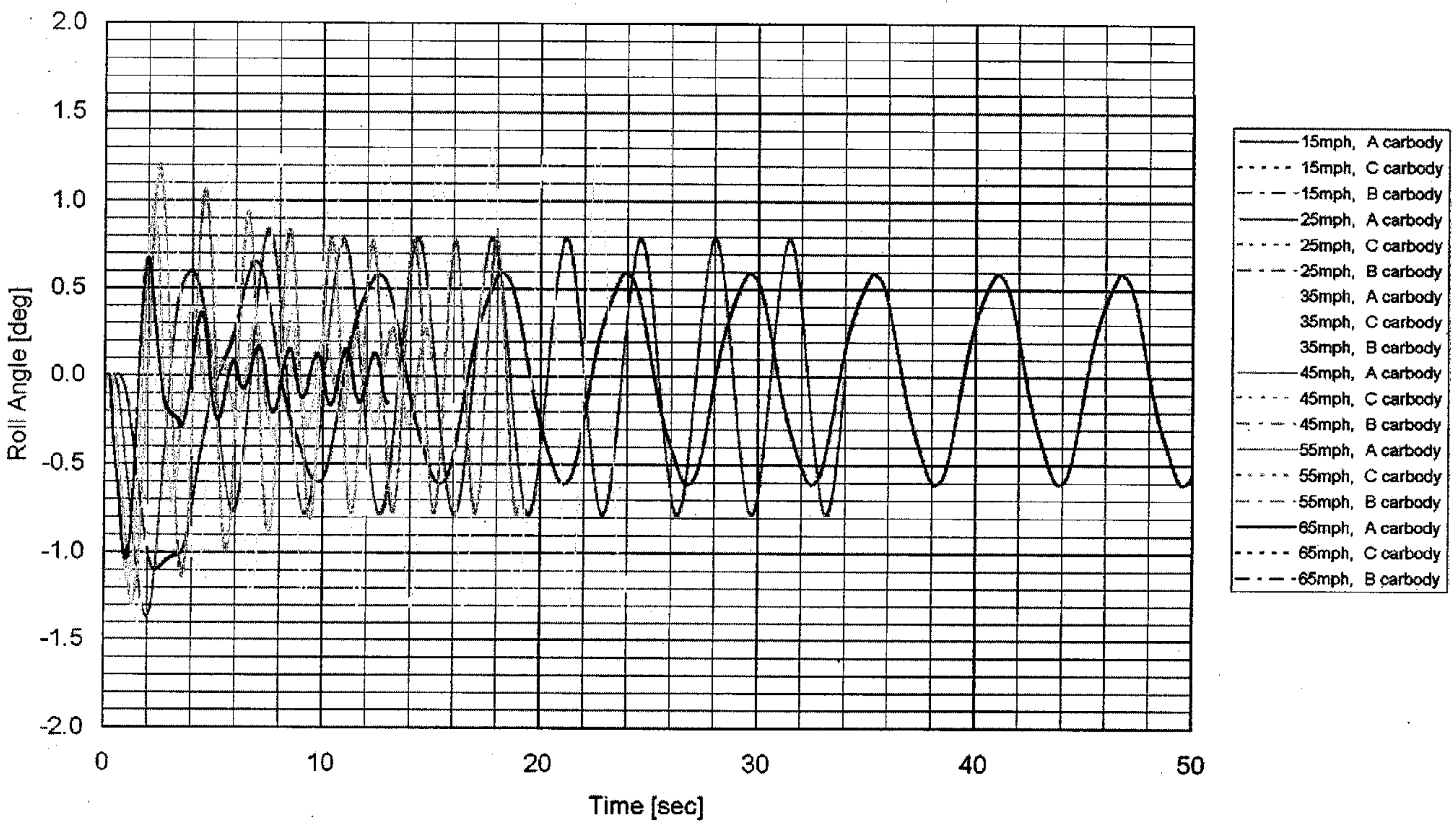


Fig.2 Carbody Roll Analysis (Case : C4-2)

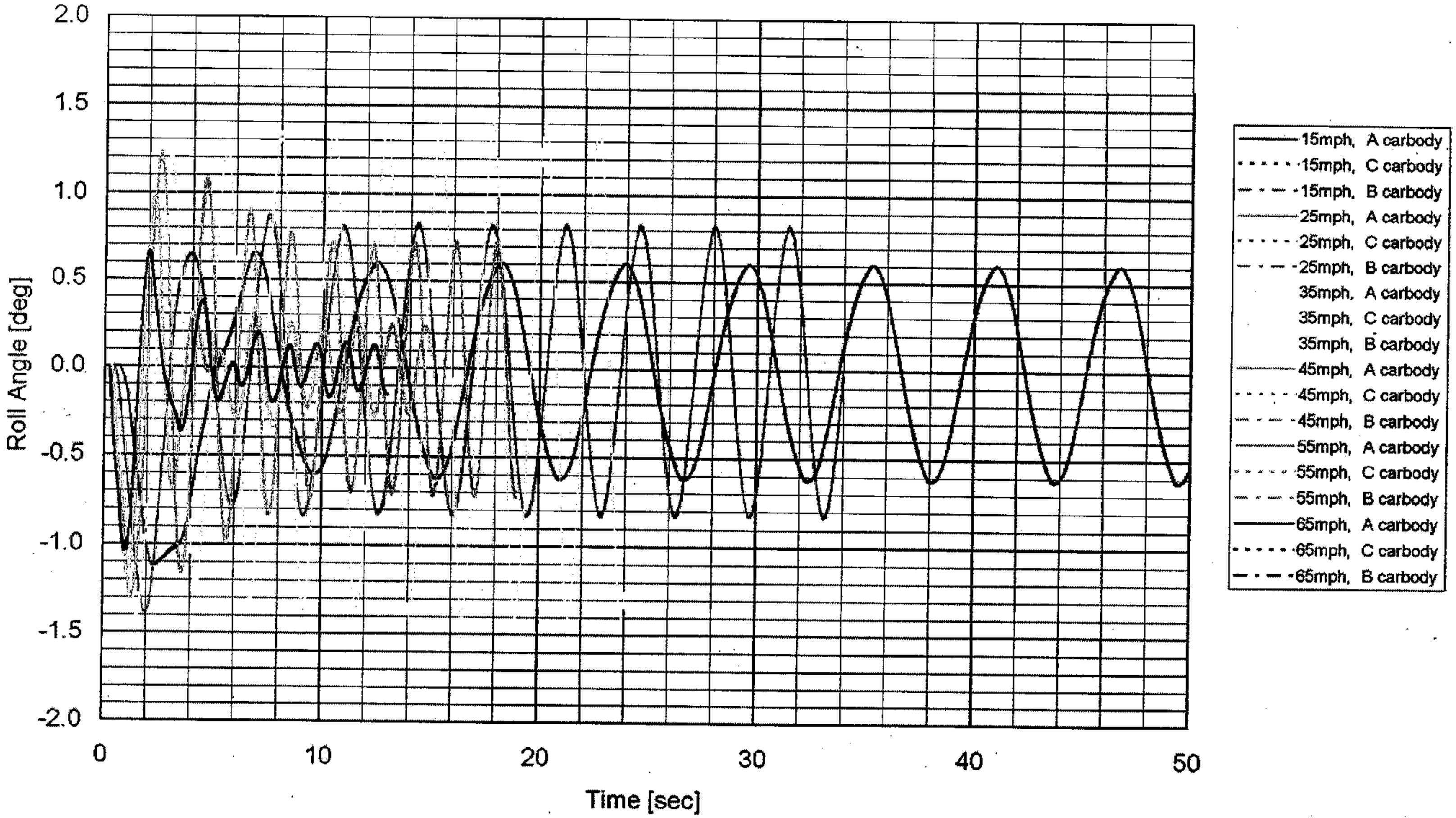


Fig.3 Carbody Roll Analysis (Case : C4-3)

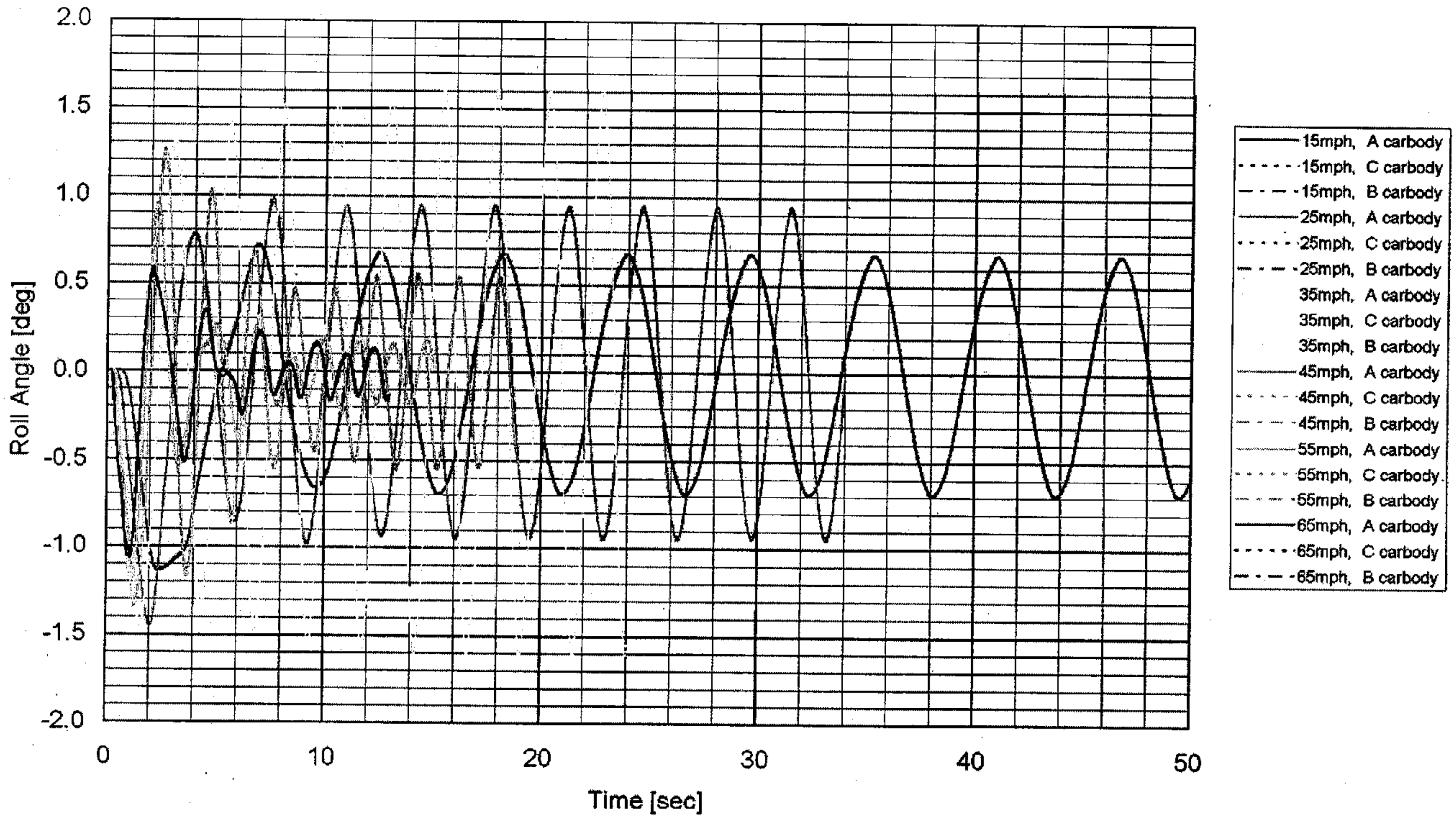
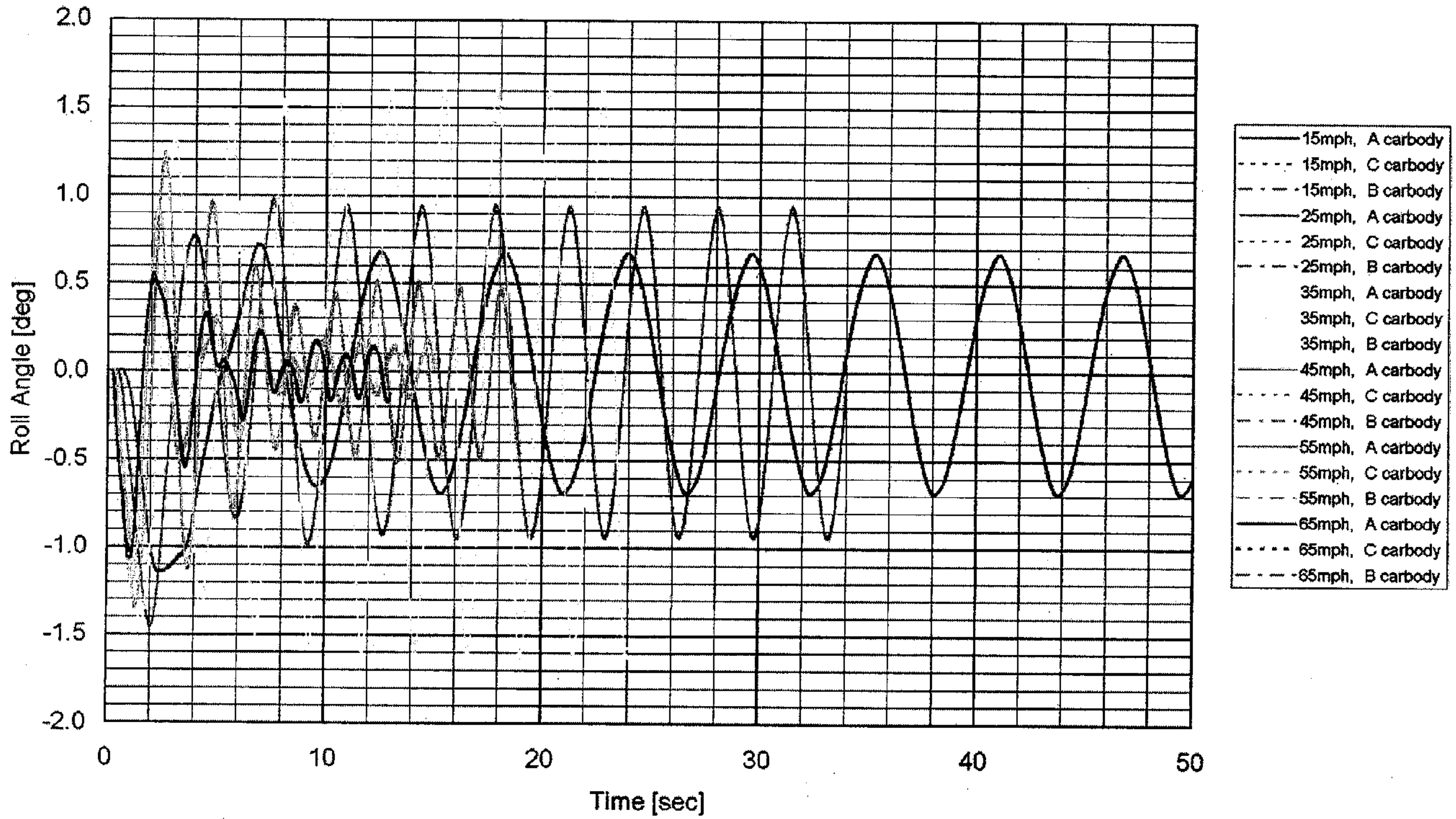


Fig.4 **Carbody Roll Analysis (Case : C4-4)**



Appendix.1

"TECHNICAL DATA OF φ 500-1 AIR SPRING"

REPORT No. 98A-5019E
9,April,1998

TECHNICAL DATA OF φ500-1 AIR SPRING

(SIZE:AP50101A13)

BRIDGESTONE CORPORATION
Industrial Products
Development Department
A.Higashidani

1.Characteristicdata (Load:73.5kN Auxiliary tank:22Lit.)

Item	Mark	Data
Pressure (MPa)	–	0.36
Effective diameter (mm)	–	φ509
Effective area change rate (cm^2/cm)	–	10
Volume (Lit.)	–	16.1
Vertical direction static spring rate(kN/mm)	0.52	0.530
Lateral direction static spring rate(kN/mm)	0.25	0.245
Lateral direction dynamic spring rate(kN/mm)	0.32	0.330
Burst pressure (kgf/cm^2)	–	20
Weight (kg)	–	35

2.Contents

(1)Static load ～ Pressure...Fig.1
(2)Effective diameter ～ Pressure...Fig.2
(3)Effective area change rate ～ Pressure...Fig.3
(4)Static load ～ Deflection...Fig.4
(5)Vertical direction static spring rate ～ Pressure...Fig.5
(6)Vertical direction static spring rate ～ Auxiliary tank...Fig.6
(7)Volume ～ Pressure...Fig.7
(8)Volume ～ Deflection...Fig.8
(9)Lateral direction spring rate ～ Pressure...Fig.9
(10)Lateral direction dynamic load ～ Deflection...Fig.10
(11)Lateral direction static load ～ Deflection...Fig.11
(12)Frequency ～ Transmissibility...Fig.12～14
(13)Stopper rubber static load ～ Deflection...Fig.15

Fig.1 Static load ~ Pressure

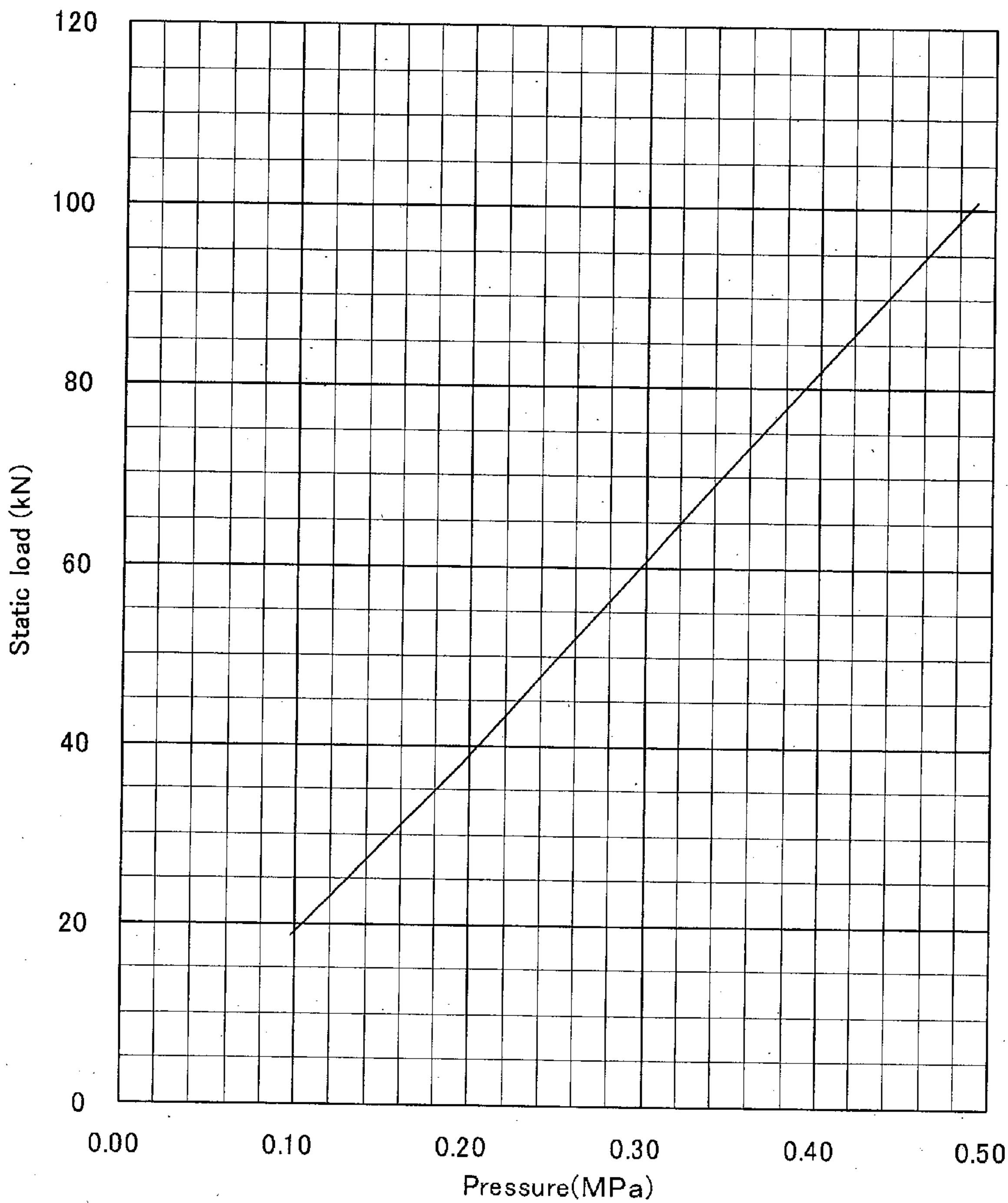


Fig.2 Effective diameter ～ Pressure

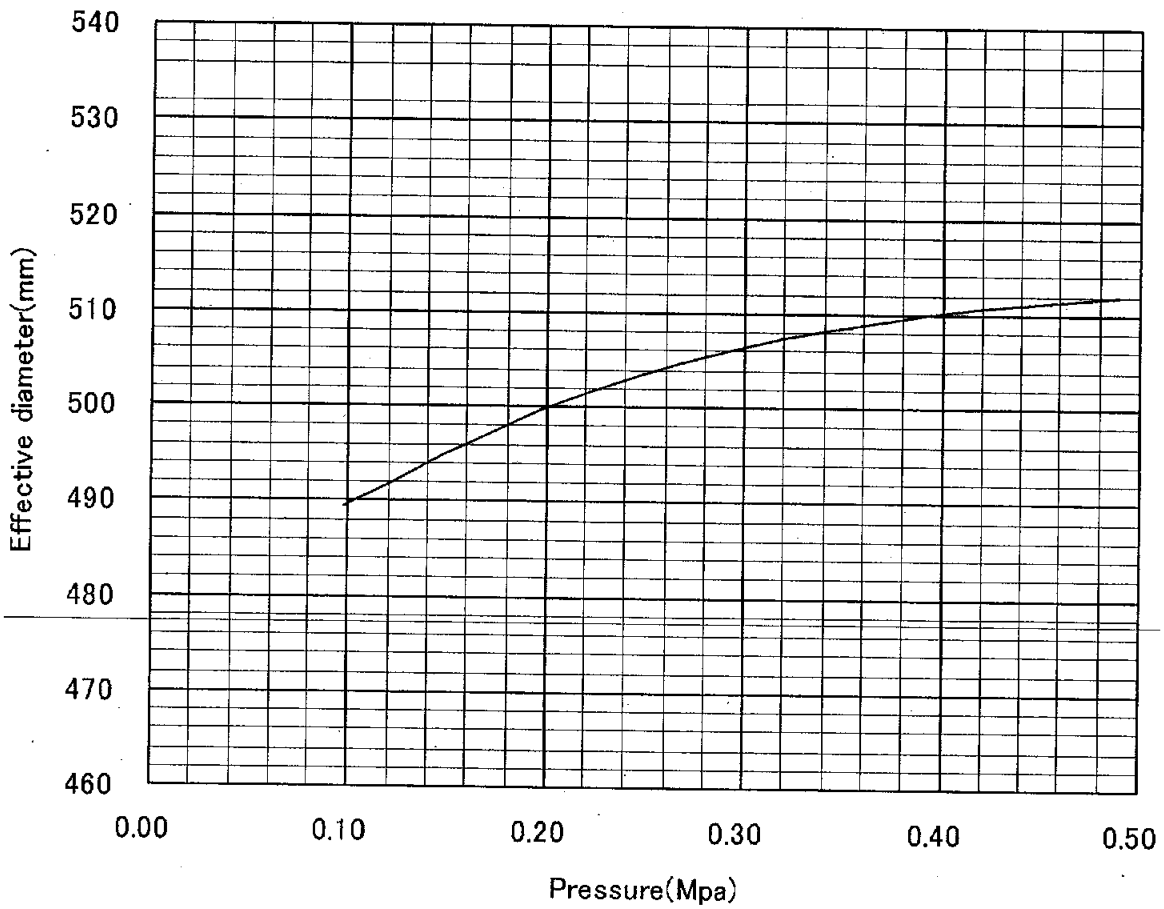


Fig.3 Effective area change rate ～ Pressure

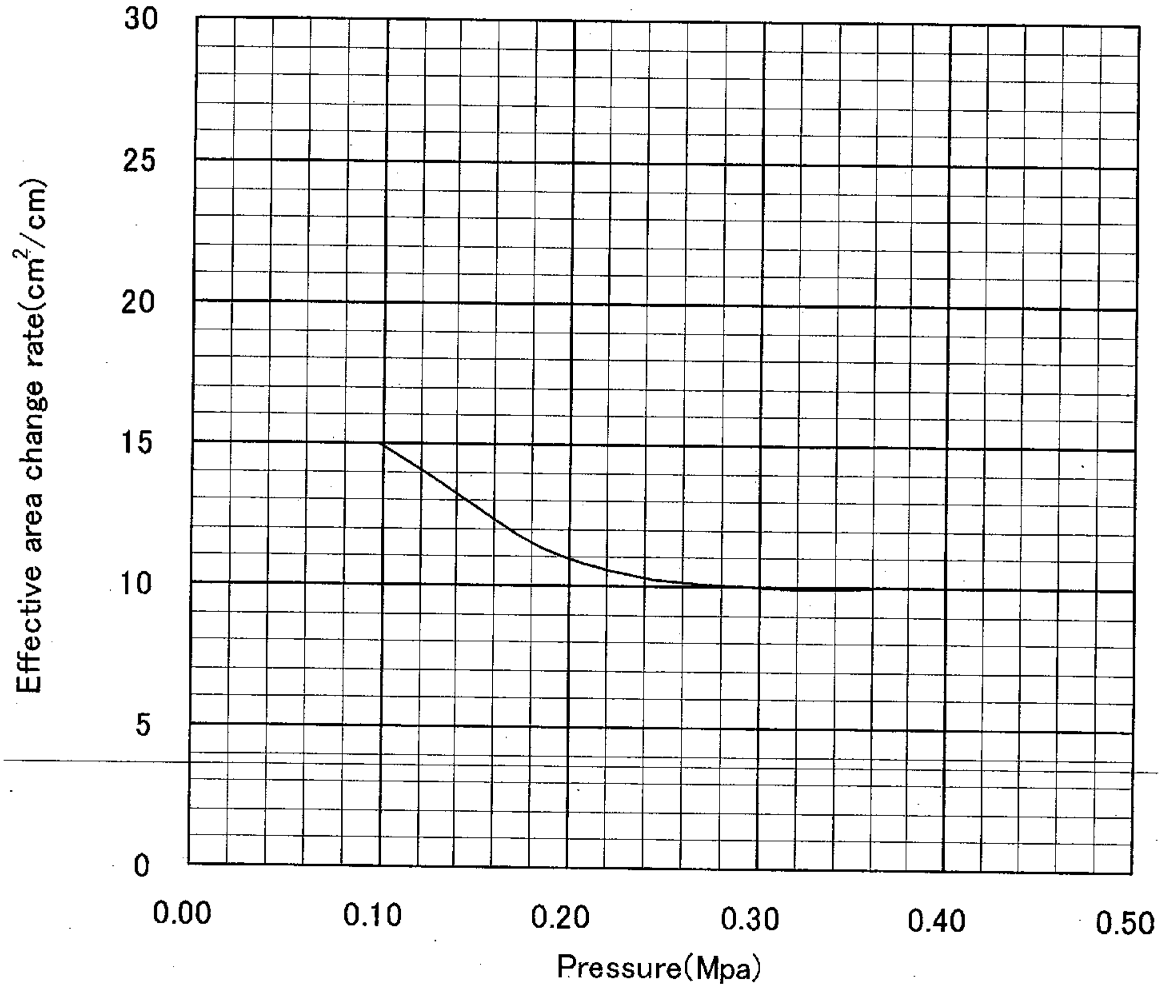
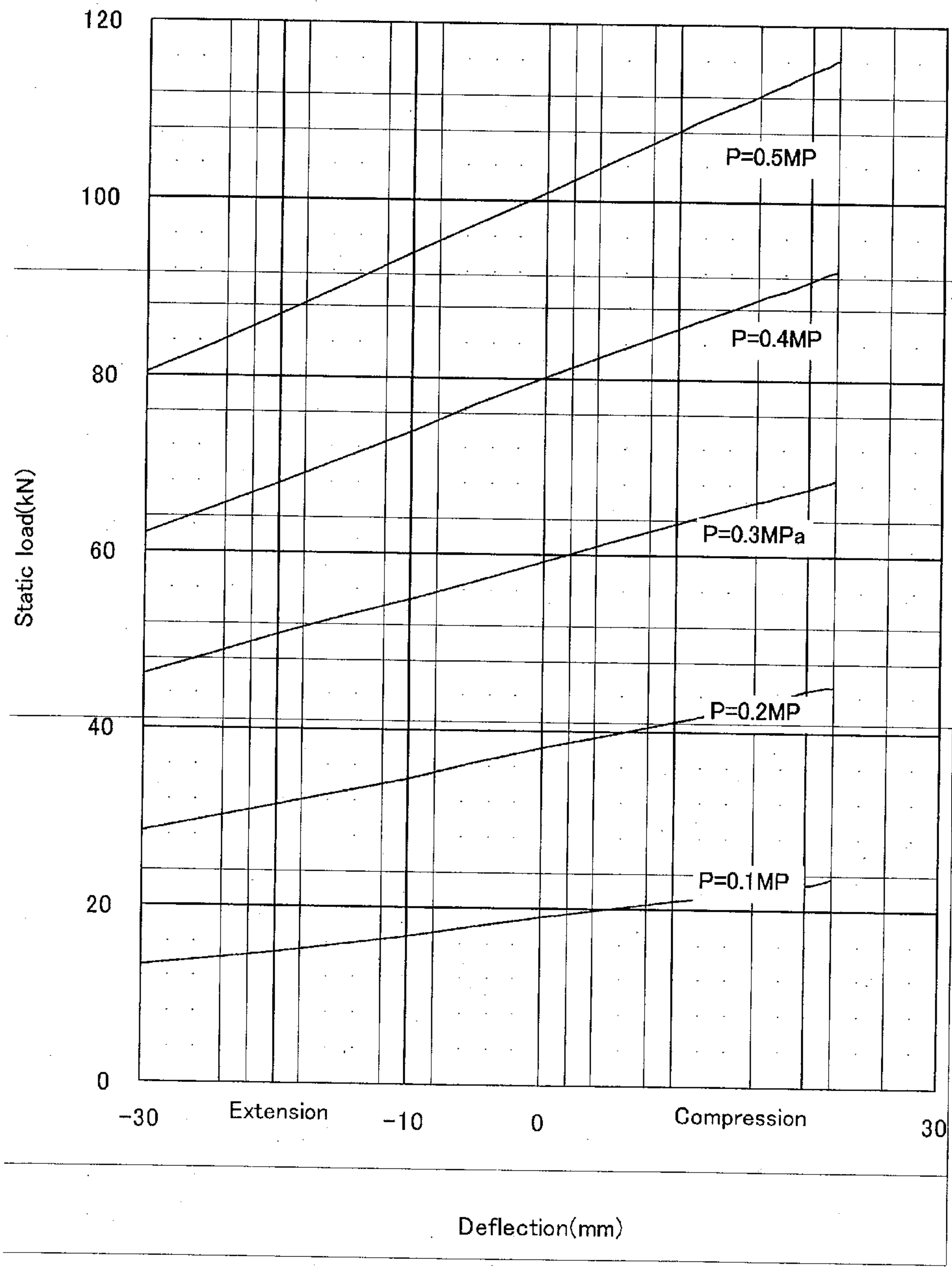


Fig.4 Vertical direction static load ~ Deflection
Auxiliary tank 22 Lit.



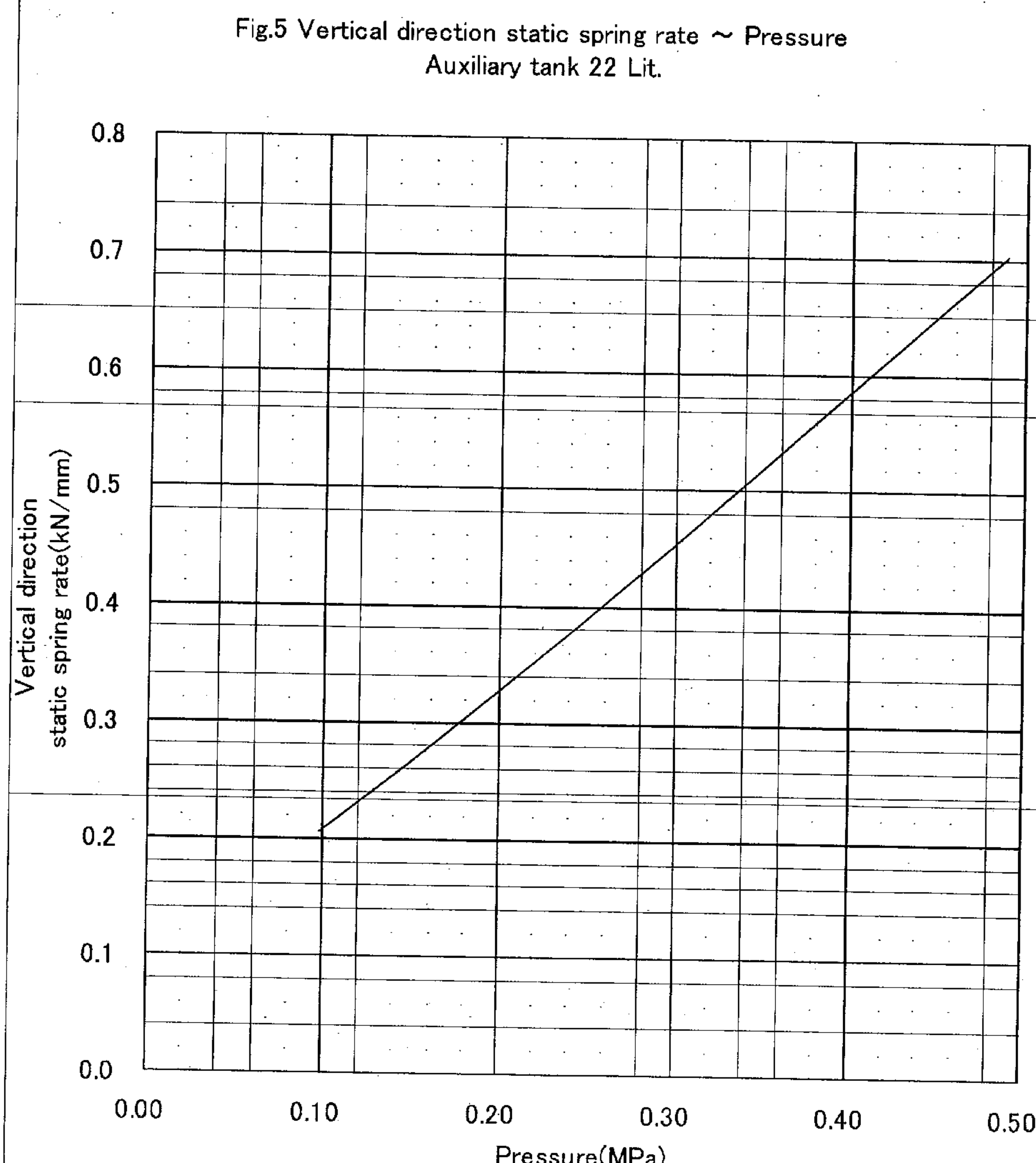


Fig.5 Vertical direction static spring rate ~ Pressure
Auxiliary tank 22 Lit.
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Vertical direction static spring rate(kN/mm)
0.00
0.10
0.20
0.30
0.40
0.50
Pressure(MPa)

Fig.6 Vertical direction static spring rate
～ Volume of auxiliary tank

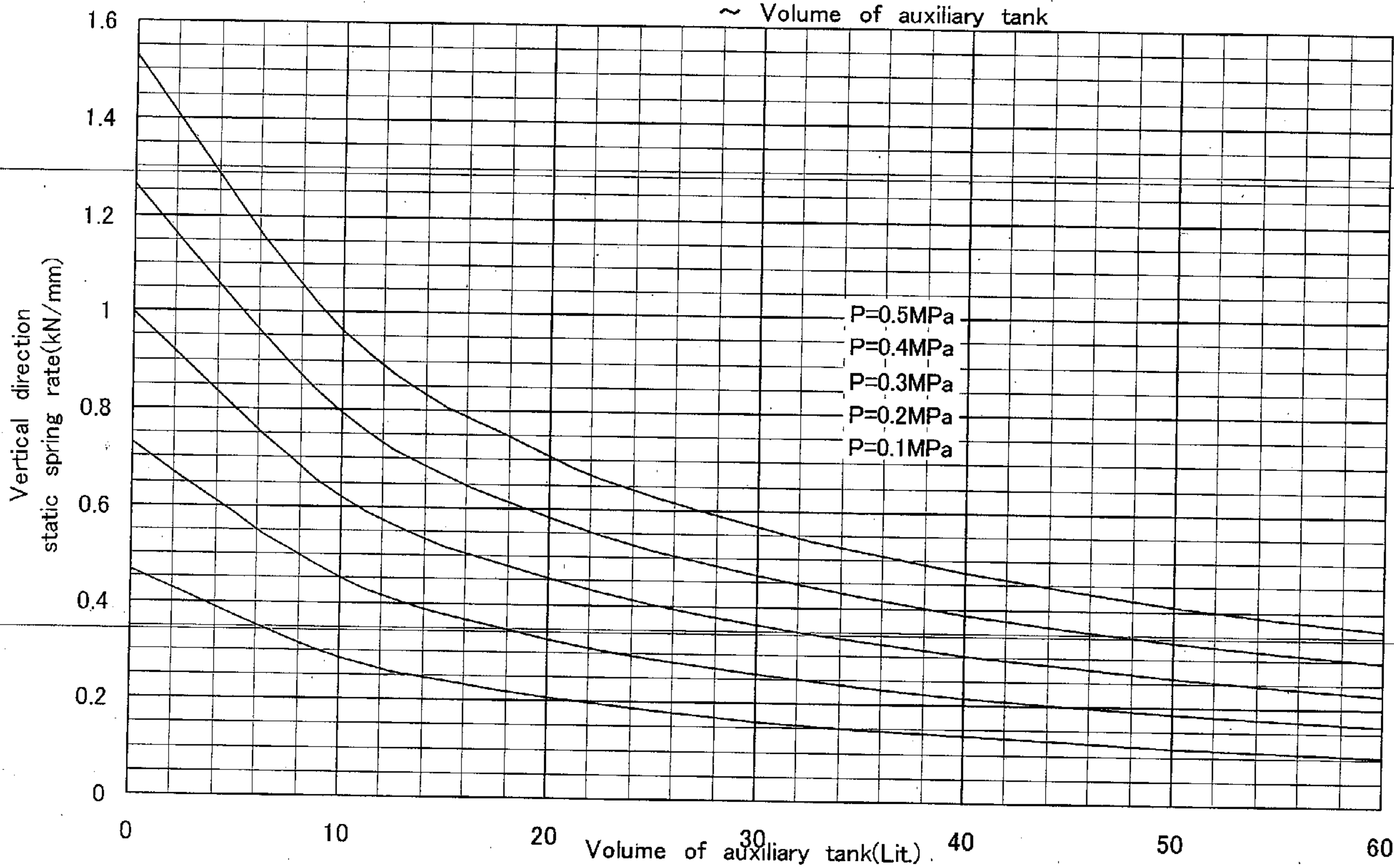


Fig.7 Inner volume ~ Pressure

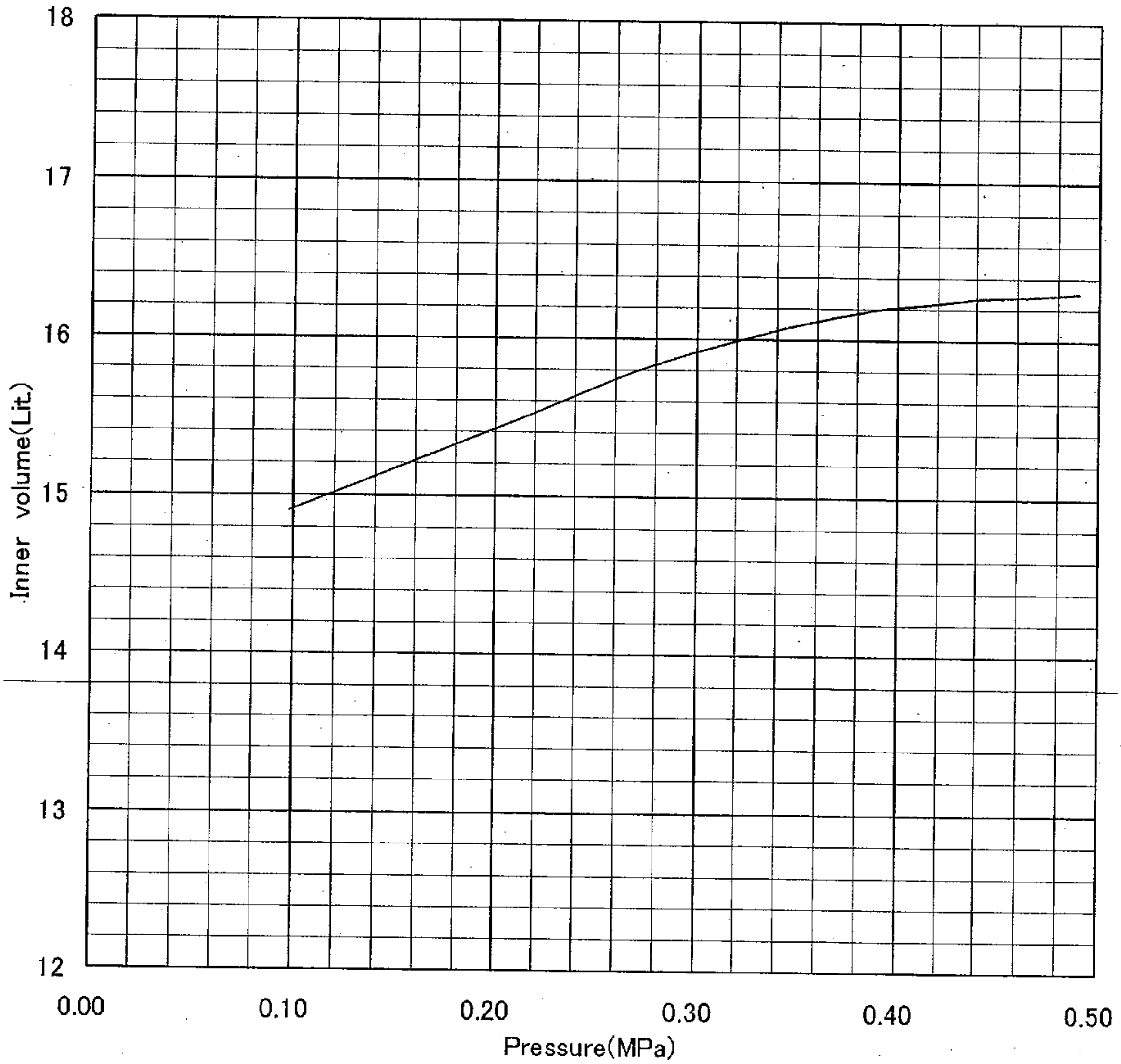


Fig.8 Inner volume ～ Deflection
Static load 73.5kN

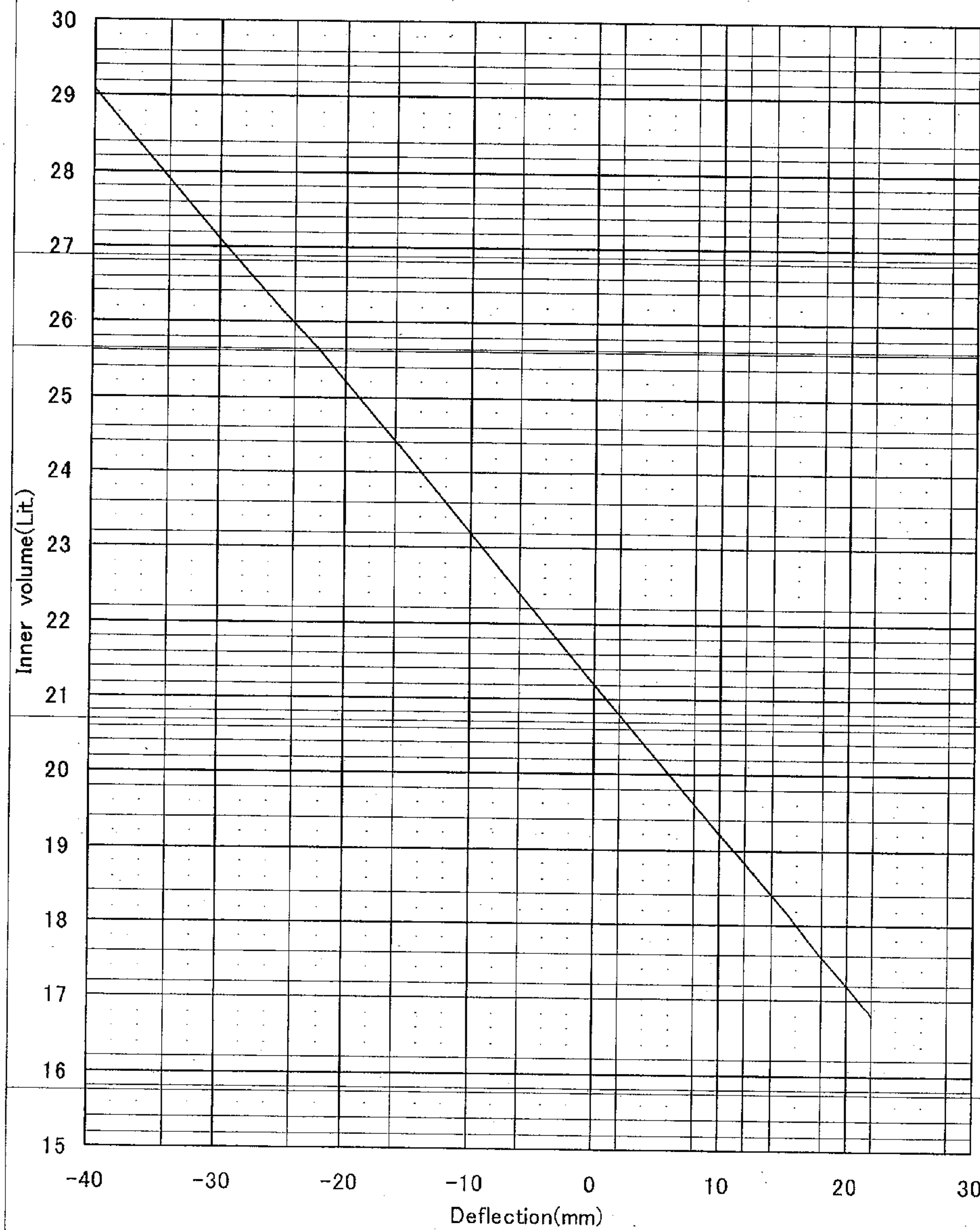


Fig.9 Lateral direction spring rate ~ Pressure

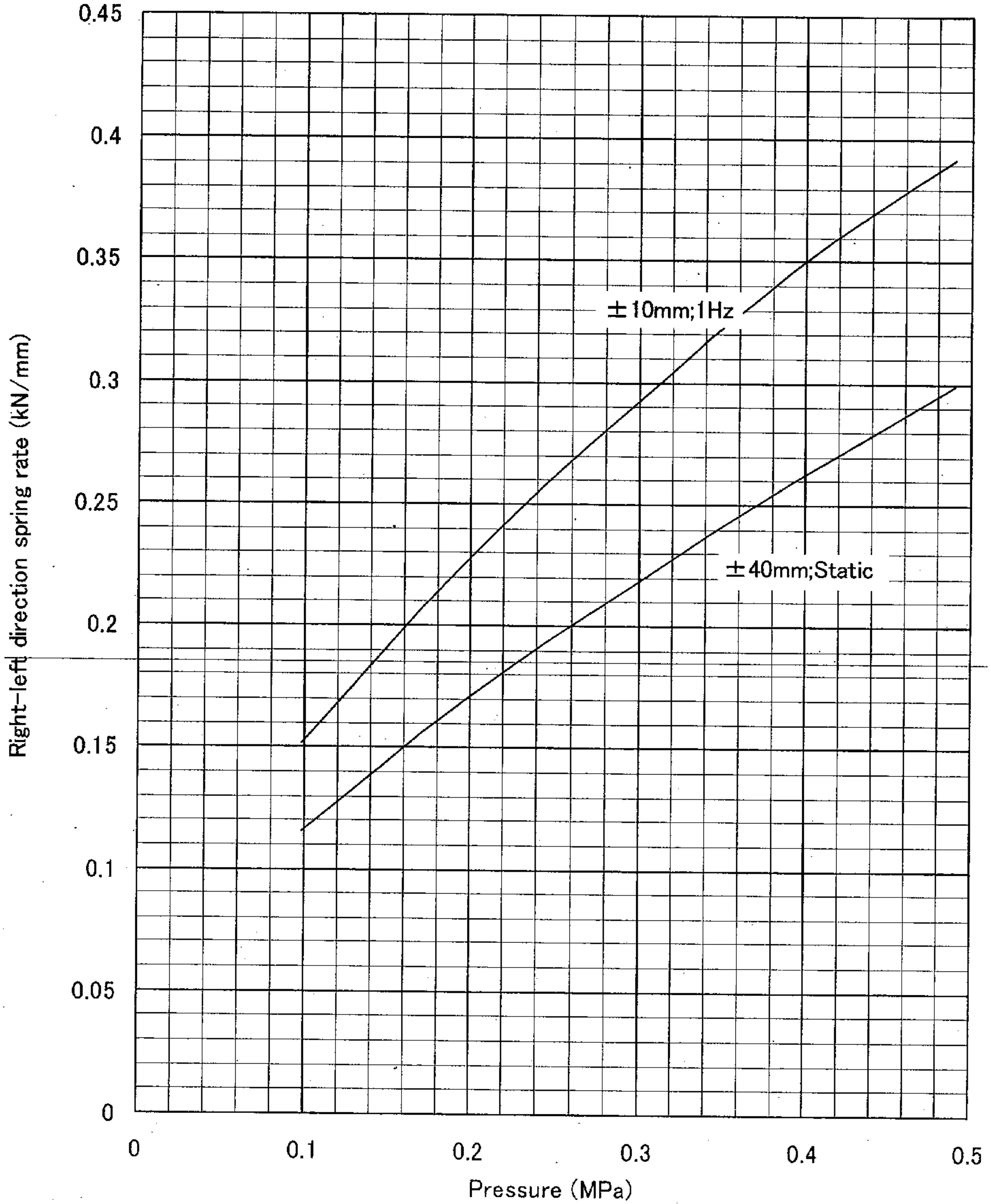


Fig.10 Lateral direction
dynamic load ~
Deflection(1Hz)

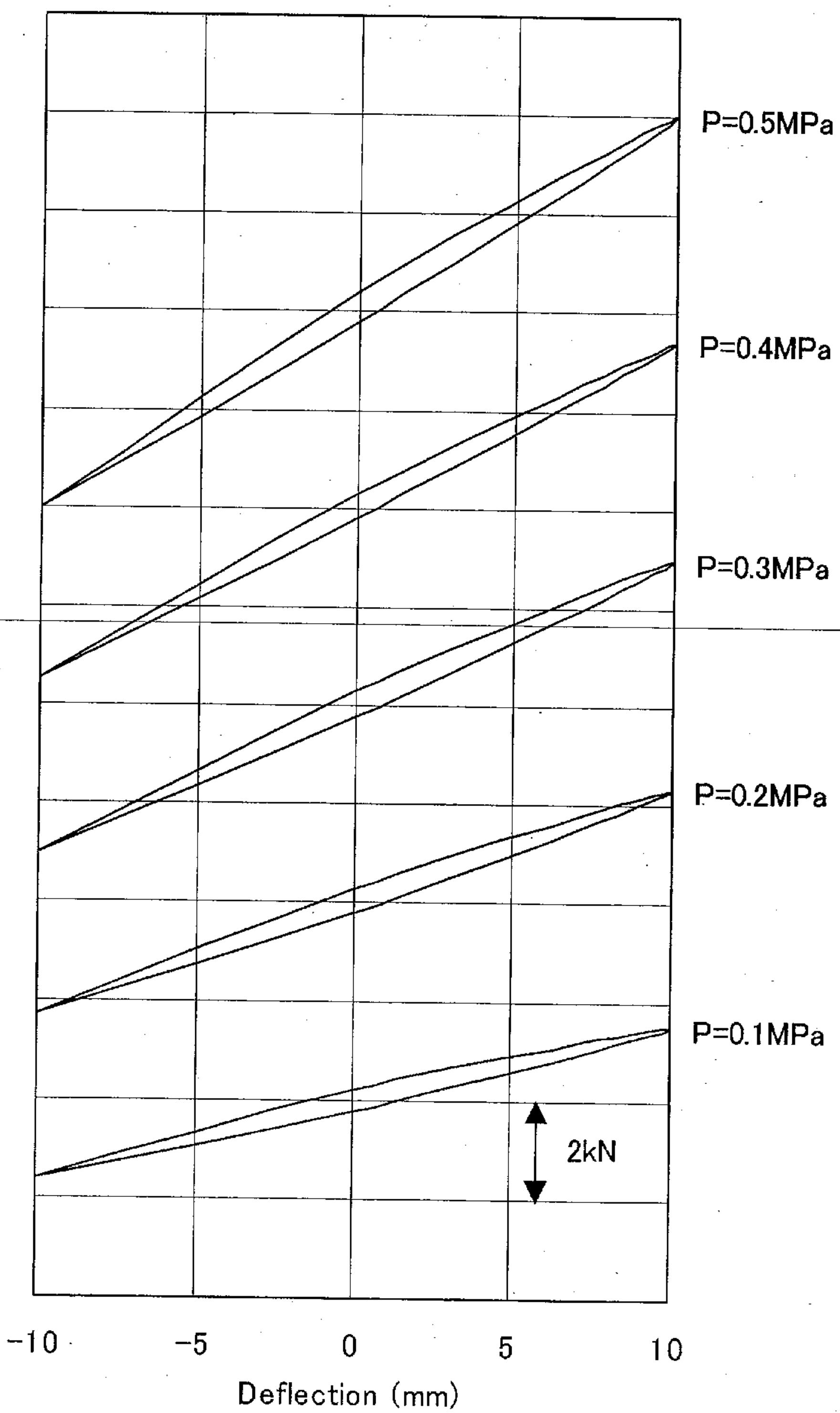


Fig.11 Lateral direction
static load ~ Deflection

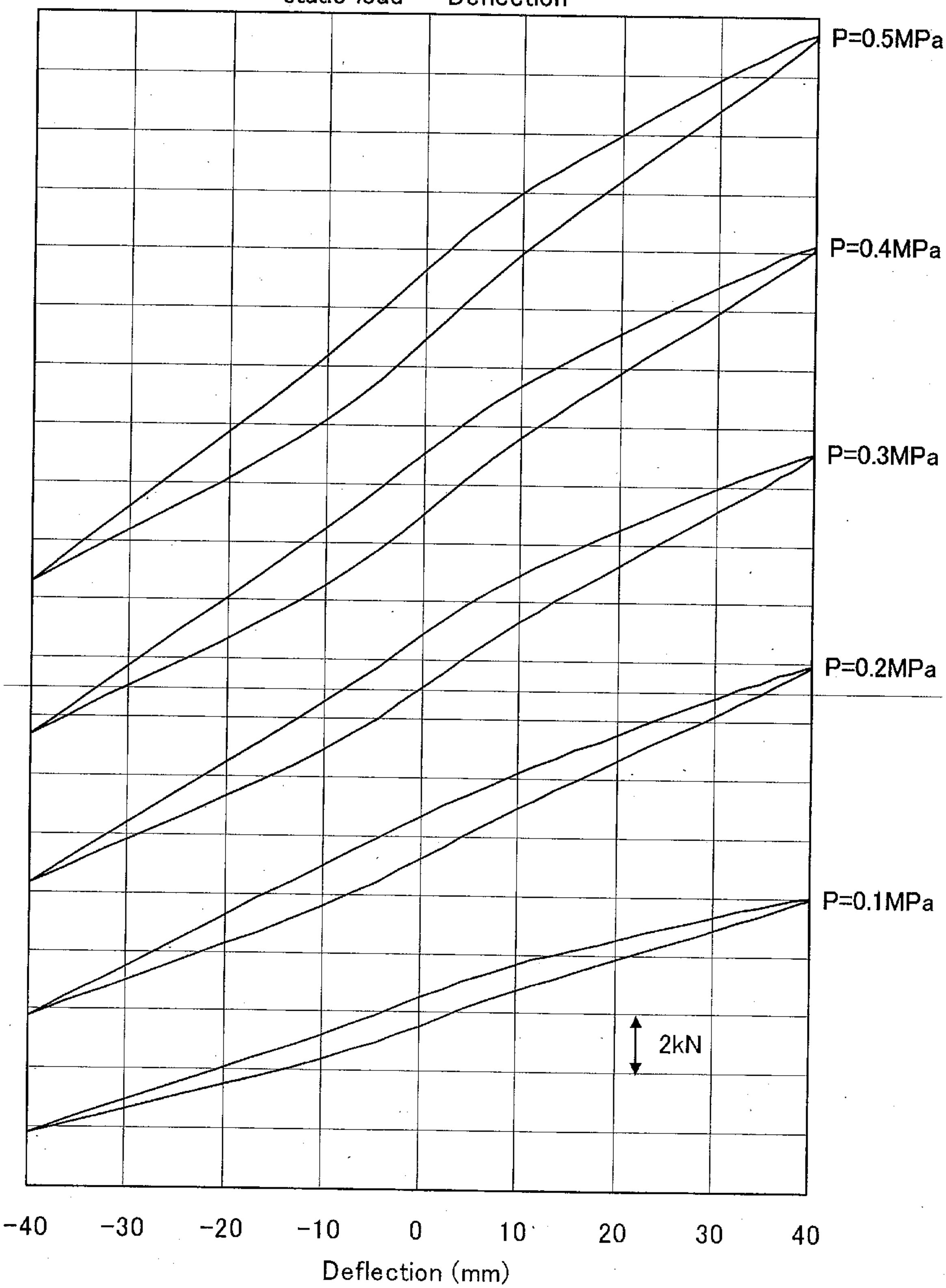


Fig.12 Frequency ~ Transmissibility
Load 73.5kN
Amplituce ±2.5mm
Auxiliary tank 22Lit.

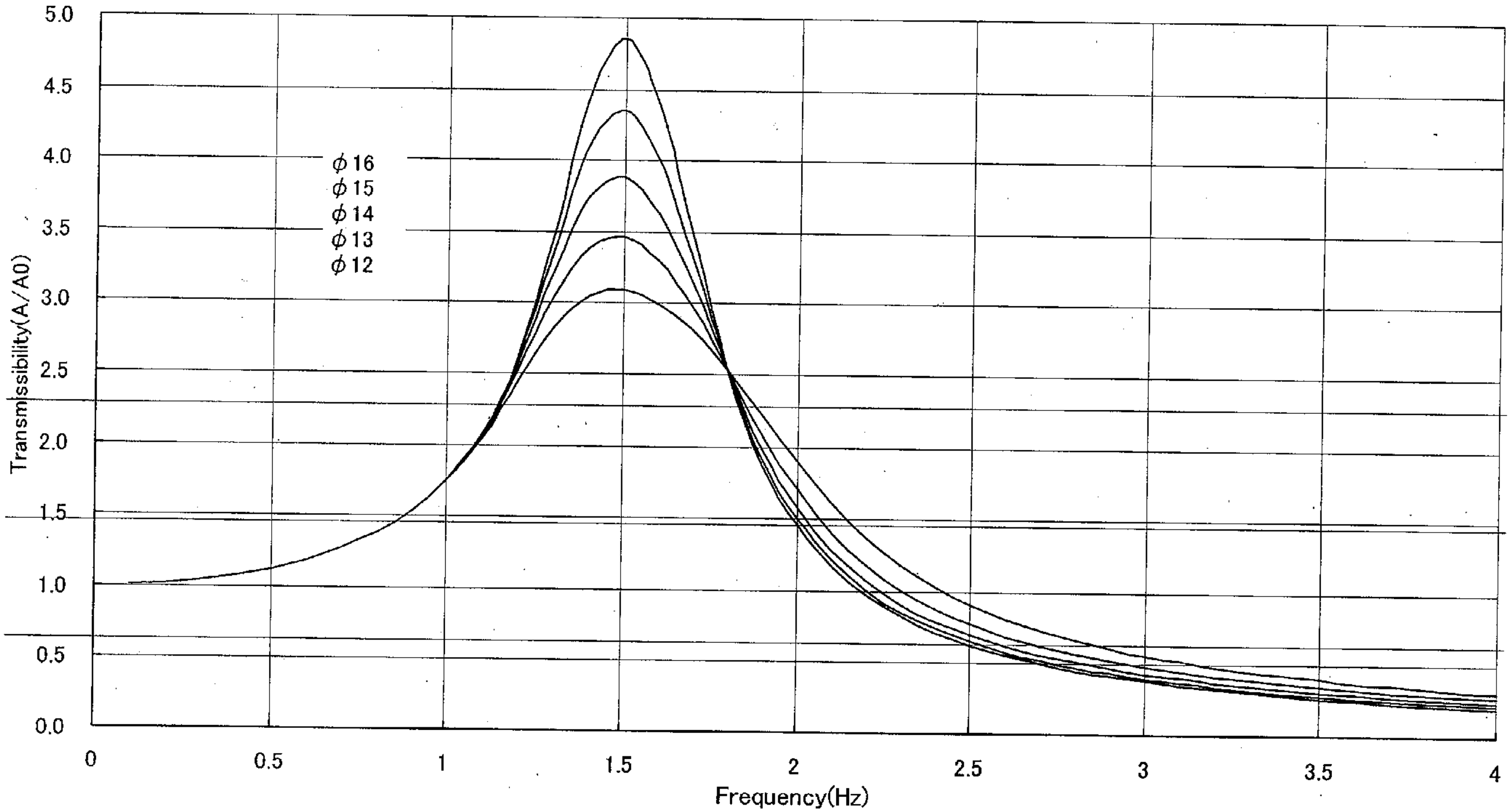


Fig.13 Frequency ~ Transmissibility
Load 73.5kN
Amplituce ±5.0mm
Auxiliary tank 22Lit.

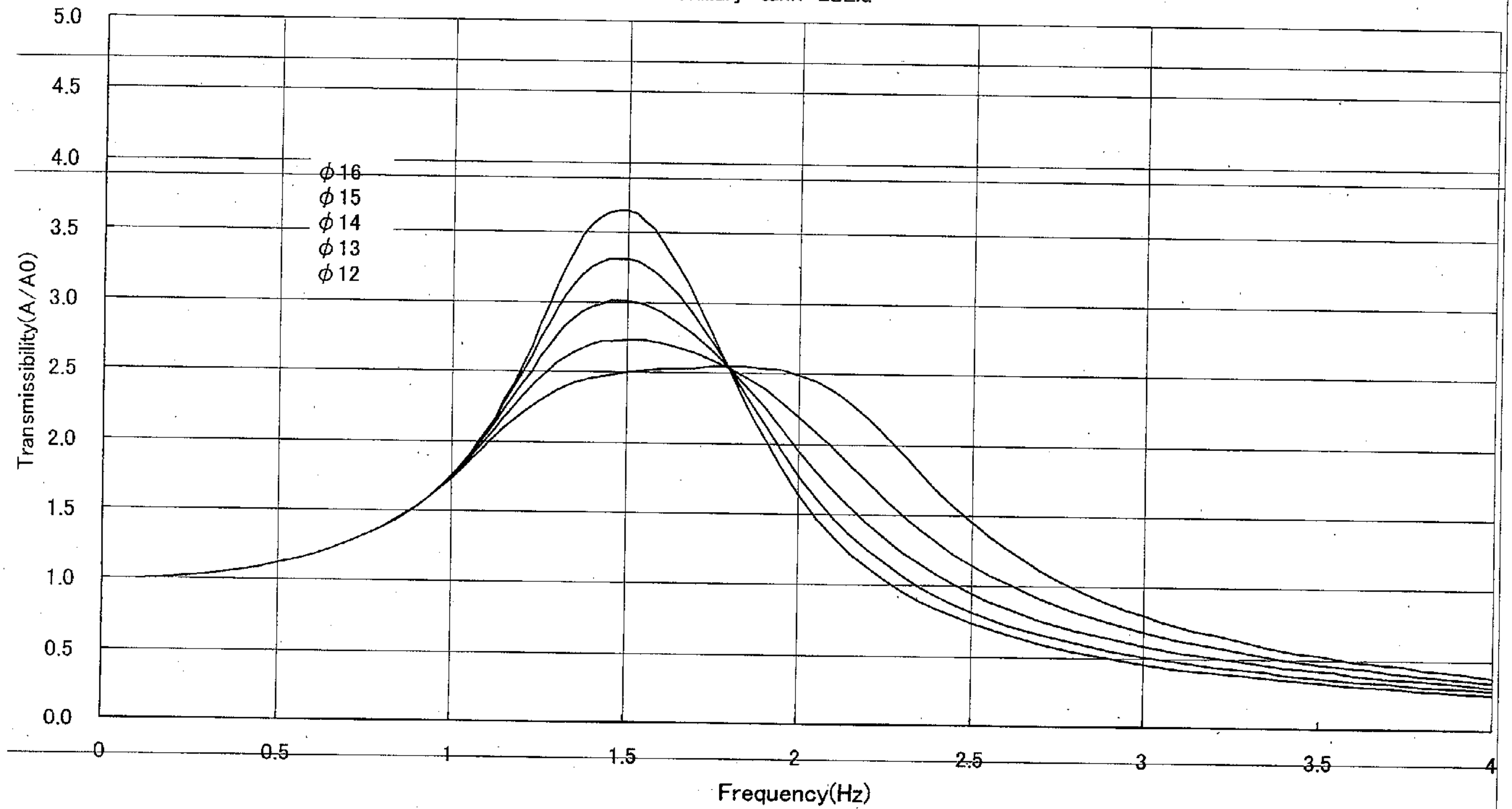


Fig.14 Frequency ～ Transmissibility
Load 73.5kN
Amplituce ±7.5mm
Auxiliary tank 22Lit.

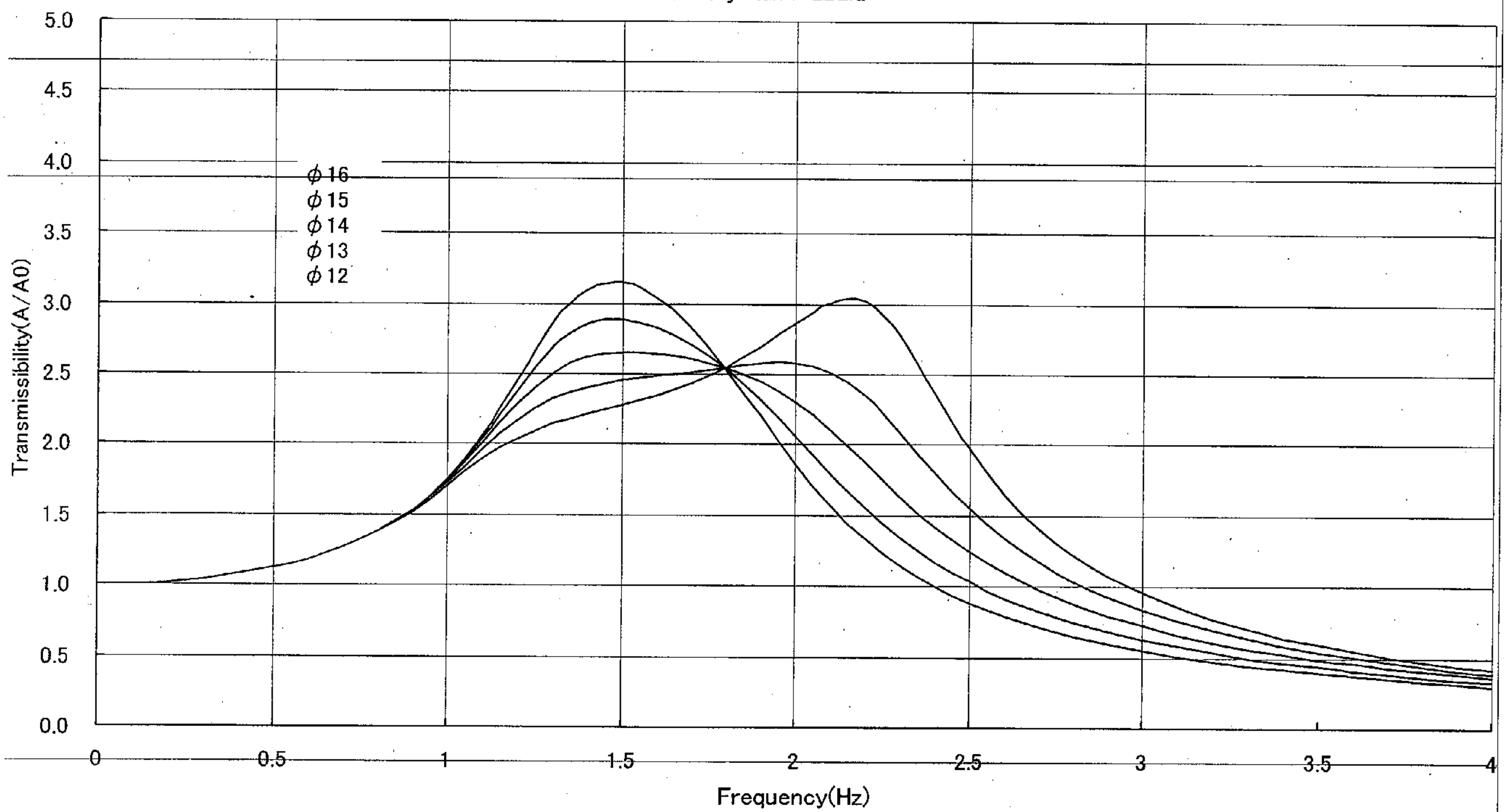


Fig.15 Stopper rubber vertical direction
static load ~ Deflection